WATER AND SOIL

W. G. Koogler

WATER AND SOIL

By

W. G. Koogler

Division of Watershed Management

Watershed Management Training Course

Region 3

1945

ACKNOWLEDGEMENTS

The introduction is from the booklet "Poverty or Conservation your National Problem" by Jay N. "Ding" Darling, published by the National Wildlife Federation.

The course also reviews a good deal from the "Southwestern Range Ecology" course put out by the Southwestern Forest and Range Experiment Station, a year or two ago, and available on most ranger districts. Appreciation is also extended to the "Southwestern" for the review and suggestions of Dr. W. P. Martin now heading up the "Influences" work at the Sierra Ancha Experimental Forest.

Since preparing this draft we have learned that one manuscript to which we owe a great deal, "Indicators for Judging Condition and Trend of Range Watersheds," by Ellison, Croft and Bailey of the Intermountain Forest and Range Experiment Station, has been submitted for publication. We hope this means that it will soon be available in its entirety and in printed form for wide distribution. In the meantime and in an effort to make sure that its findings are given local circulation and are studied and not just read, we have taken the liberty of quoting freely from the mimeographed draft.

Other publications and bulletins have been freely called upon and the suggestions of local "reviewers" freely used.

We have generally followed the policy of quoting at some length, as well as, referencing material, because of the very human failing students have for not reviewing "referenced" material and because most of the information used <u>deserves the emphasis that only comes with repetition</u>.

Water and Soil

Chapter	Contents	Page

INTRODUCTION

Conservation and History
(By Jay N. "Ding" Darling)

Some day a new historian will arise who will revolutionize our study of the past and give us a much better understanding of the problems which we ourselves are meeting. This new history will give us an interpretation of the causes which produced the events, rather than a compilation of dynasties, dates and victorious generals. Instead of telling us in detail how Genghis Khan and Alexander the Great fought their battles, the new historian will tell us why they fought their wars of conquest. And the reasons will exactly parallel the causes which led the Japanese to invade the Asiatic continent, the Italians to slaughter the Ethiopians and Hitler to shatter all the international covenants to loot Europe. From the first racial conflicts of written history on down to the present day, wars have sprung from the same background: An increased racial population wore out its natural resources and relieved the pressure within by arming its surplus men and moving in on the less depleted pastures of its neighbors.

Archaeologists tell us that this process started in the Gobi Desert and whether or not that was the cradle of the human race, the fossilized remnants of profuse vegetation and abundant animal life are all that remain to show that man once lived there in obvious abundance until depleted natural resources forced the inhabitants to seek new lands. Out of this area came successive waves of migrations which moved westward into Mongolia, India, Persia, Arabia, Turkestan, Palestine, Mesopotamia, the Nile and the Sahara, the Caucasus, the Mediterranean state and finally into what we now call continental Europe.

Buried in the dust and rubble of ages along these ancient migration lanes are crumbling palaces of kings and buried cities which once housed thriving populations, convincing evidence that those desert lands were once sufficiently productive to maintain prosperous communities. You couldn't pasture a healthy Dakota grasshopper there now on 100 square miles. Fabled lands "flowing with milk and honey," the valleys of the Ganges and Euphrates, Arabia, Persia and Babylon were not always the deserted wastes they are today, inhabited only by struggling remnants of the former hordes searching an exhausted land for sustenance for their flocks and a meager livelihood for themselves. Architects and artisans do not go off into a desert to erect such majestic designs to masonry as mark the remains of Bagdad.

What vast natural resources must have blossomed on the sandy wastes of Egypt to support the armies employed to build the Pyramids! For every stone in their vast bulk there must have been at least a hundred acres of land in full and continuous production to feed the laborers who quarried the rock and hoisted it into place. Let your imagination fill the gap between the vast operations during the building of the temples of Karnak and this flea-bitten remnant of Egypt which dips from the Nile enough water to raise a handful of rice, the per diem ration of its remaining population.

Few know that the mysterious city of Timbukto, a ghost town of prehistoric origin isolated by miles of arid waste in the middle of the Sahara Desert, was once surrounded by fertile fields and olive groves. Buried beneath its desert sands is complete evidence that Africa's great "dust bowl" once was as rich as the Mississippi Valley. Giant primitive forests, lakes and rivers once spread across the vast wastes of the Sahara.

Between the Gobi Desert and Mesopotamia, a thousand Genghis Khans, Attilas and Neubuchaadnezzars fought for the riches which these ancient lands once produced. They wouldn't be worth fighting for now if it were not for the oil deposits (of which the ancients had no knowledge) hidden deep beneath the earth's crust. And speaking of Dakota grasshoppers, as I was a moment ago, is a reminder that grass-hopper plagues and human migrations, like "the Colonel's lady and Judy O'Grady," are sisters under the skin. Both come about through populations expanded beyond the tolerance of the food supply and when they migrate both seek a new location where vegetation is rich and plentiful. Both leave desolation in their wake and when they have exhausted the food supply of their latest invasion they move on to another. It takes no imagination on the part of anyone who has ever seen a grain field after the grasshoppers have finished it to see there the replica of man's migration path down through the ages.

Is it just a coincidence that those once rich lands where civilization has lived the longest are all now deserts and unable to support a one-thousandth part of their former populations, or is there a lesson which we have overlooked hidden in crumbling ruins of departed civilization? Could it be that our own falling water table, dried-up springs, man-made dust bowls and abandoned cattle ranges are the early symptoms of the same blight which turned the ancient garden spots into deserts? The scientists who have read the hieroglyphics written in the sands of time say it is not a coincidence but an invariable rule. Other scientists, seeking a formula by

which we may avoid such a future, have given us assurance that, taken in time, soils, vegetation and subsoil water tables can be made to persist indefinitely and yield a balanced production of life's necessities.

Fragmentary translations of ancient hieroglyphics give hints of further illuminating data on internal conditions which precede those early tribal migrations and resultant interracial conflicts of old. They are the only hints but they tally so accurately with known cycles of modern social upheavals that they leave room for more than a suspicion that there is a standard cycle of social and economic phenomena directly associated with the disappearance of natural resources.

Boastful praise of riches and self-glorification marked the writings and arts of newly established principalities on new and virgin lands. A note of social discontent crept into the ancient records when drought and pestilence smote the flocks. (Sounds like Kansas, Arkansas and the Dakotas.) Shepherds staged a revolution which was put down by the King's Guards. Labor complained of the high price of food. Redistribution of wealth was strongly advocated as a cure for the social discontent and was tried but whether it did any temporary good or not the cycle of event went forward as per schedule and when natural resources had been pretty well used up the government proceeded to pick a fuss with their neighbors which resulted in a war of conquest and the pressure of population on natural resources was relieved, probably only until the new pastures gave out.

From the National Wildlife Federation publication "Poverty or Conservation Your National Problem" - By Jay N. "Ding" Darling.

WATER AND SOIL

Chapter - I - Precipitation and Streamflow

Being unable to make it rain we must make the most of what rain we get. Perhaps, therefore we need to take a closer look at our water situation from the standpoint of what becomes of the precipitation that does occur. The old question of where the rain comes from and where it goes has been broadly answered by studies of the water (hydrologic) cycle. The workings of this cycle which are dealt with as we go along may well prove worth reviewing not only as they are related to the various phenomena making up the cycle but more particularly with respect to the influence of land management on the way these factors work out on the ground.

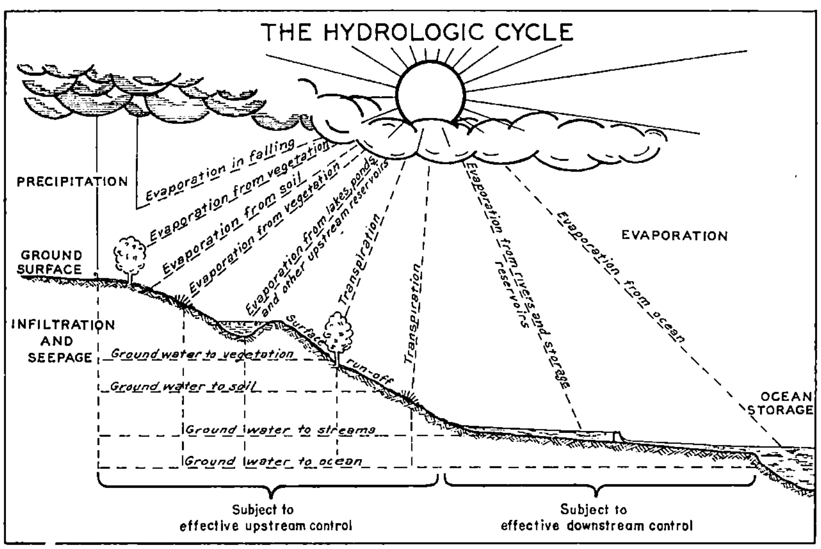


FIGURE 1.-Earth waters have a natural circulation known as the "hydrologic cycle." (U.S.D.A Misc. Publication No. 397)

The cycle starts with the origin of precipitation from moisture condensation in the air. Sometimes the condensed moisture fails to reach the surface of the earth because of .....

Interception

Falling as rain, snow or hail the water is first subject to interception by trees, shrubs and other objects extending above the surface of the earth. Sometimes our light summer showers are almost wholly intercepted by the forest canopy and undergrowth vegetation. In such instances the moisture is again evaporated without ever having reached the ground......even had it reached the ground in such small quantity it would probably have been evaporated from the earths surface without having served a very useful purpose. Forest Service studies indicate that from 12 to 40 percent of the summers rainfall may be intercepted by vegetation. Needless to say, summer showers so light as to be principally intercepted are of little importance so far as seasonal volume growth is concerned but such occurrences yield a partial explanation of what happens to some of the recorded rainfall that is difficult to account for.

Fig. 2 - Interception of precipitation by trees.

This factor of interception also has its advantages since it is of no mean importance in reducing run-off from large storms as a measure of flood control. By no means all of the precipitation intercepted is again lost by direct evaporation and probably something under 5% of the total precipitation is accounted for by direct evaporation of intercepted moisture since in heavy storms as soon as the interception capacity is filled the continuing precipitation reaches the soil where it percolates into the ground, runs off the surface or evaporates.

Infiltration

Rain falling on protective vegetative mats, or melting snow running down the stems of plants or grass into loose, undisturbed soils sinks readily into the ground. The amount of precipitation thus accounted for varies greatly with the character of soils and the condition of the surface, i.e., its receptiveness, intensity of the storm and other factors. If the ground is highly compacted, frozen or already filled with water very little additional water can be accommodated. Of the total water that is taken into the soil some is brought to the surface by capillary action and evaporated, some is taken up by vegetation and evaporated again through the processes of plant transpiration, and the remainder makes up the ground water that sustains lake levels and the flow of springs and perennial streams. This base flow of streams is of fundamental importance in maintaining irrigation water supplies.

Surface Run-off

When the intensity of rainfall or the melt of snow exceeds the rate at which the water is able to percolate into the soil, surface run-off commences. The rate or volume of surface run-off depends on many factors

such as depressions or roughness of the surface, slope, evaporation and infiltration into the soil as the water passes over the surface. The longer the period of time that the surface flow is in transit and the slower it moves, the greater the opportunity for continued infiltration and the greater the reduction in surface flow with proportionate increase in ground water storage. The rate and volume of surface run-off are the governing factors in the regulation of streamflow and control of floods.

Rivers and streams are the connecting life lines between the arid lower valleys with their favorable crop climates, and the mountains where precipitation is relatively abundant. Region 3 streamflow originates at elevations upwards of 4500 feet elevation, largely within the national forests. In addition to the storage of snow in the mountains there is also a distinct correlation between elevation and total precipitation, notwithstanding certain differences due to prevailing wind currents or other causes. To illustrate this, correlation curves for elevation and precipitation and for precipitation and run-off were prepared by Hardaway and are shown on the accompanying charts 1 and 2.

These charts illustrate conditions on the Apache National Forest. There elevations fall off sharply on the Arizona side, the drop in elevation apparently accompanied by an increase in winter rainfall along with an increase in total precipitation even at relatively low elevations. For this reason separate curves were prepared on chart 1. It will be seen that as a rule the total precipitation increases with elevation until the curves finally converge at about 8700 feet. Chart No. 2 illustrates the approximate correlation between

CHART I

PRECIPITATION-ELEVATION CURVES FOR APACHE NATIONAL FOREST

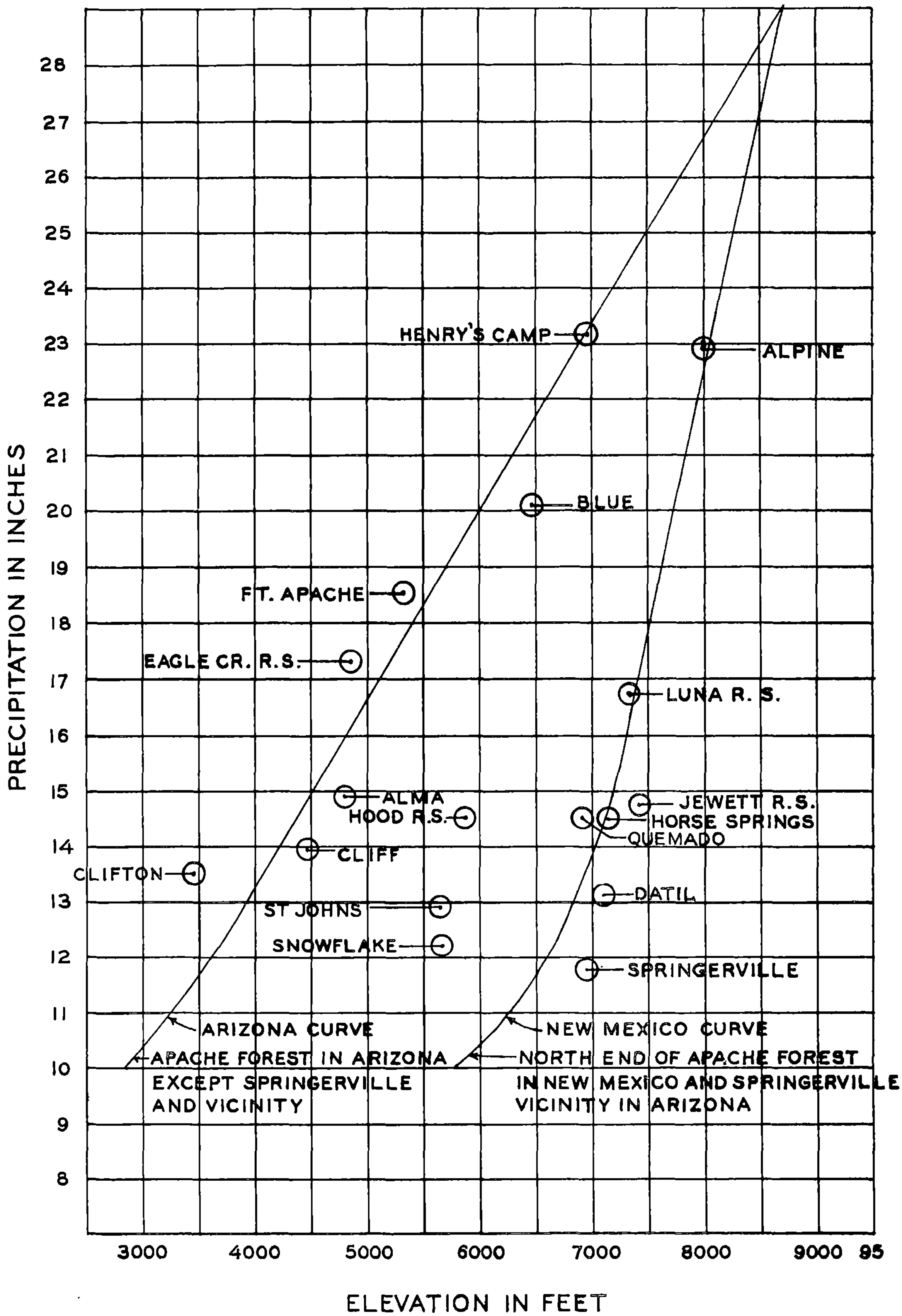
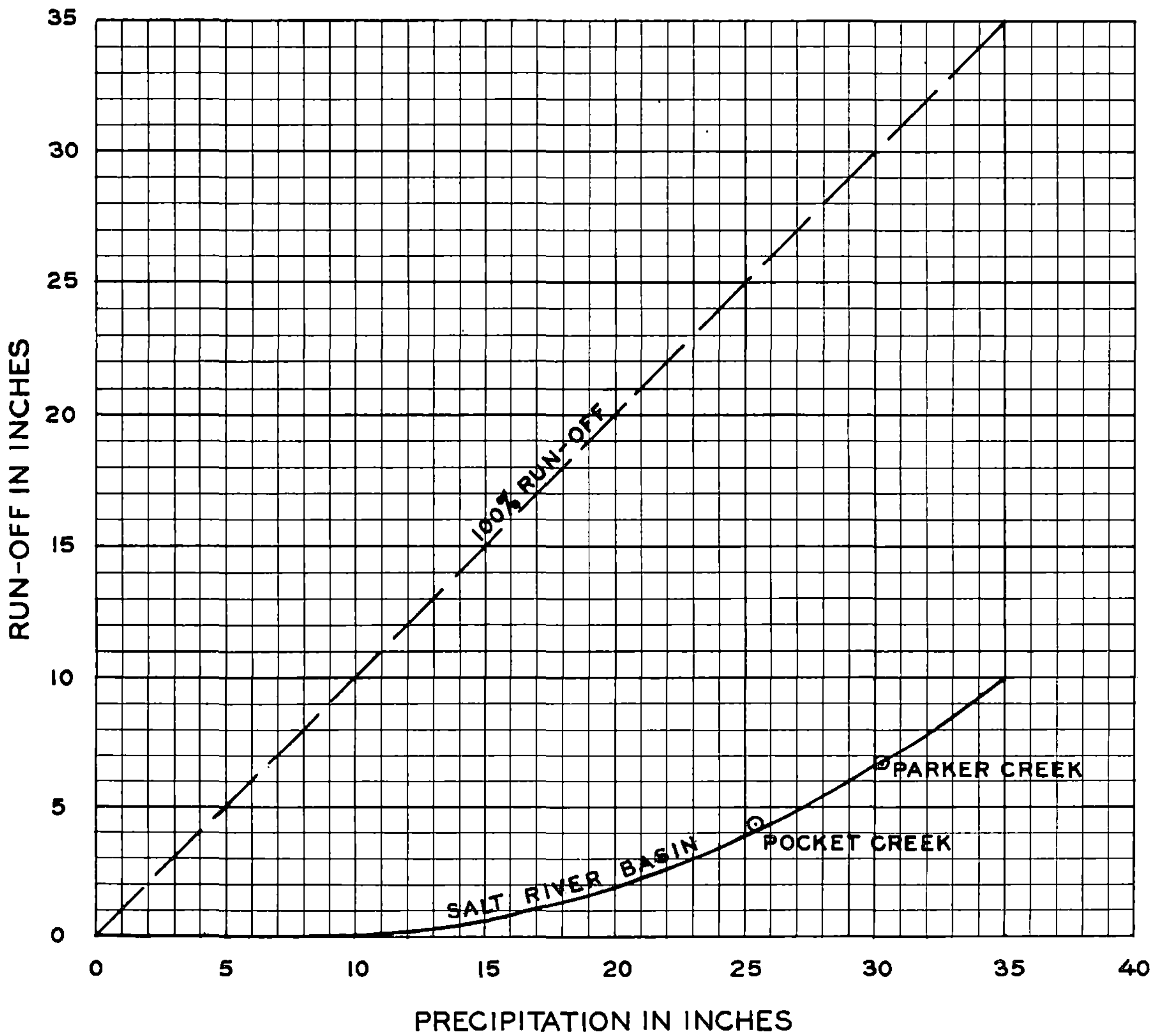


CHART II

PRECIPITATION-RUN-OFF CURVE FOR SALT RIVER BASIN



G.D.H.

precipitation and run-off for the Salt River basin. Due to greater winter rainfall when evaporation is low, more run-off is likely to result from a given amount of precipitation in the Salt River basin than takes place in some of the other drainages of the State, but very little run-off results in any case where watersheds receive less than 15 inches of precipitation annually. Although some run-off is indicated on Chart 2 for precipitation of less than 15 inches it is small and comes from flash floods due to hard summer rains. On Chart 1 it will be noted that 15 inches annual precipitation is not recorded on the curves at less than 4500 feet elevation and perennial streamflow originates above that point. For general purposes, therefore, the 4500 foot contour marks the lower limit of important water yielding area.

The natural infiltration and water holding capacity of soils is usually of less concern in this region than are the modified infiltration and water holding capacities of the soil brought about by denudation and soil compaction, accelerated erosion and exposure of sub-soils or parent formations.

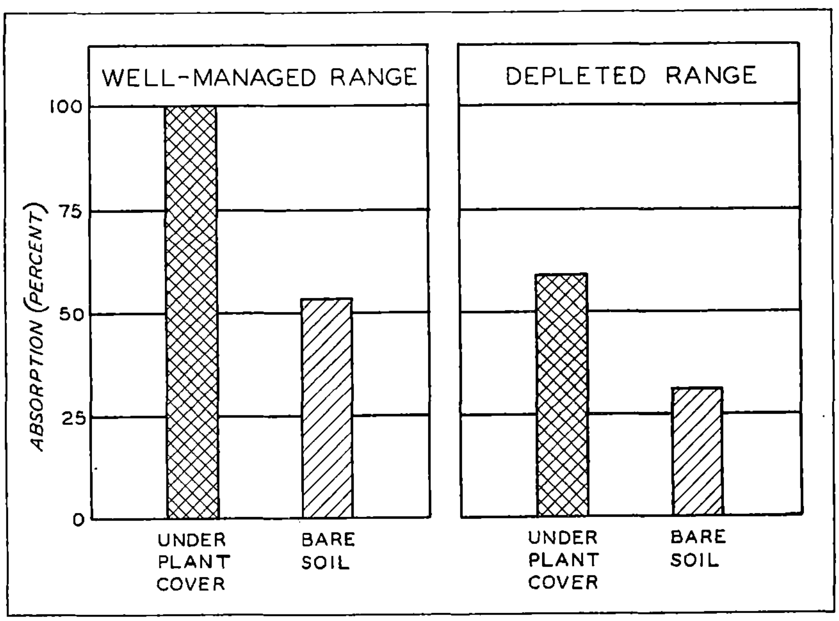


FIGURE 3.-THE EFFECT OF DEPLETION ON ABSORPTION.

Where plants are present, the rate of absorption of water by the soil is materially increased over that on bare soil. It is significant also that bare soil on well-managed range land absorbs water more rapidly than similar spots on overgrazed range. The data shown here are taken from averages obtained on plots on the Boise River watershed. Absorption under plant cover on well-managed range was at the rate of 0.44 inches per hour.

FROM WESTERN RANGE

Excessive run-off, in conformity with gravitational principles follows lines of maximum gradients in cutting its way to established base levels. Large gully systems tend to quickly concentrate run-off into cutting heads heavily charged with silt and debris. These hugh silt loads not only add to flood hazards by aggrading the lower valleys but add directly to the destructive power of the flow by increasing its density and force. The key to streamflow regulation therefor insofar as we can influence it through natural means lies in the control of surface run-off. This in turn depends largely on the inherent or modified condition of soils as related to their infiltration and water holding capacity.

Evaporation

Evaporation takes place from water surfaces, from the ground, from other surfaces and from vegetation in the form of transpiration. In 1930, Lowdermilk found, in a study of California watersheds, that if all rain in southern California were to occur as 1/2 inch storms one week apart that evaporation would account for practically the total supply of meteoric water.

Transpiration

In the life processes of vegetation, water plays just as essential a part as it does in the case of man. Grasses, trees and other plants use water from the soil in growth and maintenance and give off water vapor. Data on transpiration rates for vegetative types of the southwest are woefully lacking but certain transpiration experiments carried out at the Sierra Ancha Experimental Forest indicate that in this country, with its low soil moisture content and high evaporation rate, the protective influence of vegetation in reducing direct evaporation

almost offsets the transpiration water used by the plants. As shown in the following table, the loss of water from bare surfaces from evaporation alone proved to be 95% as great as the combined losses of transpiration and evaporation from vegetated surfaces.

Table 1

(Data from Southwestern Forest and Range Experiment Station)

Year	Precipitation Inches	Total Water	Evaporation in Inches (Includes Transpiration) Bare Ground	Dead Ceanothus Cover	Live Ceanothus Cover	Live Side Oats	Live Buck Wheat	Free Water Surface
1939	25.68							
	°2.50	28.18	22.56	21.86	24.33	23.34	22.73	74.79

°Water added

Of course, where large quantities of soil moisture are available to plants, such as cottonwoods along stream courses, they transpire a great deal more rapidly and use a great deal more water. Likewise where plenty of water is available as from a free water surface evaporation may average 75 inches a year but where the annual precipitation rate falls to 10 or 15 inches a year, the evaporation rate from land surfaces must be accordingly modified just as nature adjusts the transpiration rate of plants to the quantity of water available. Evaporation then, in its various phases and including transpiration from plants, is the final step in the water cycle which begins with atmospheric moisture and includes condensation, precipitation, interception, infiltration, run-off, and evapo-transpiration to a state of atmospheric moisture again.

The factors of the water cycle that man can expect to manipulate most readily are, (1) "infiltration, absorption, and evapo-transpiration processes, the last through his

control of the plant cover. To the extent that absorption and infiltration can be increased, surface run-off and storm flow can be reduced. It is here that watershed control measures designed to increase soil cover and the content of organic matter of soils, and to effect other changes which retard run-off, may be expected to operate. The upstream control measures are intended, in short, through vegetation, proper land-use practices, water-retarding devices, etc., to maintain or increase the utilization of the capacity of the soil as a reservoir."

Chapter - II - Soils

Soil Classifications

Soil is defined as the substance of the upper stratum of the earth which furnishes nutriment to plants or which is particularly adapted to support and nourish them. Perhaps even a more significant function of soil is to provide a place for water storage. The infiltration and water holding capacity of the soil therefore are major factors in regulating run-off and maintaining vegetative associations. In this discussion we are not so much interested in studying soils from the standpoint of technical classification as we are in analyzing their physical characteristics and functions as reflected in the land management problems on every ranger district. There seems very little to be gained therefore by going into an extensive study of the scientific classification of soils. A brief discussion of soil classification methods however seems in order in explanation of common classification terms.

Artificial Soil Classifications

Soil classifications have frequently been developed to meet particular needs. Where such classifications are designed to meet some human need or use they are termed artificial classifications. By and large such arrangements are based on the mechanical composition or texture of top soils. The designation of soils in accordance with this scheme is probably the oldest of all methods apparently having originated with the concept of such terms as sand, clay and loam. Four major soil groups are recognized as based on texture: gravels, sands, loams and clays. Mechanical methods of classification are still very useful and many minor soil classes have been described. Weir (2)

lists some of these as follows:

Principal Soil Textures
(Name in Order According to Clay Content)

Texture	Limit in Percentages of Soil Separates: Sand Percent	Silt Percent	Clay Percent
Coarse sand	80 to 100°	Less than 15 percent silt and clay	
Fine sand	80 to 100°°	Less than 15 percent silt and clay	
Loamy sand	70 to 100°°°	From 15 to 20 percent silt and clay	
Sandy loam	50 to 80	0 to 50	Less than 20
Loam	30 to 50	30 to 50	Less than 20
Silt loam	0 to 50	50 to 100	Less than 20
Sandy clay loam	50 to 80	0 to 30	20 to 30
Clay loam	20 to 50	20 to 50	20 to 30
Silty clay loam	0 to 30	50 to 80	20 to 30
Sandy clay	50 to 70	0 to 20	30 to 50
Silty clay	0 to 20	50 to 70	30 to 50
Clay	0 to 50	0 to 50	30 to 100

°Including fine gravel.
°°Containing 50 percent or more fine sand and very fine sand.
°°°Containing 35 percent or more fine gravel.

Other artificial classifications include such broad character groupings as alluvial (water borne), colluvial (gravity accumulations below a cliff), sedimentary (water deposited by sedimentation), loess (wind deposited), and drift (glacier deposited). Some classification groupings have been based on soil color, still others on geological groupings with respect to the rocks from which the soil-forming materials have been derived, etc.

Scientific Soil Classifications

The basis for scientific soil classifications was apparently established by the Russians, who at the start were interested only in broad geographic soil groups and who at first did not define local soil types. Their classifications however became more and more to be based on definite soil characteristics as their work developed. This early development work by the Russians was followed by Marbut after the publication of some of their work in 1914.

According to Weir the presently accepted scientific method for the grouping of similar soils is (11) by natural distinguishing characteristics that have developed as the result of soil forming forces acting on deposits of geologic materials that had originated through rock weathering. The characteristics of a soil may be best determined by studying a vertical section, or profile, which reveals from the surface downward its morphology (physical constitution, layers, and structure) and other features like color, texture, and chemical and biological aspects of the different layers. Some typical soils may express definite stages of change in like geologic materials, as may be indicated by certain closely related soils that may represent undeveloped, poorly developed, well developed and even degraded stages. Such stages are best expressed by soil profiles. Incipient stages are indicated by the absence of soil layers, and well developed stages are shown by district layers and by sub-soils (B horizons) which are commonly heavier textured than the topsoils (A horizons). In between these two stages areintermediate or poorly developed soils.

Soil classification nomenclature takes three special factors into account: (a) series, (b) type, and (c) phase.
Broadest of these classifications is the soil series, i.e., series include soils developed from similar parent materials, but differing in the texture of the A horizon. Each series has its characteristic range in climate and relief. Soil series are given names taken from places near where the soils were first defined as: Mohave series,

Roswell series, etc. The definition of soil type is identical with that of its soil series except that the texture of the A horizon within a type is essentially uniform. Thus, there may be one or more types within a series, differing only in the texture of the upper 6 or 8 inches of surface soil as: Mohave loam and Mohave sandy loam, each representing a type of the Mohave series.

A soil type phase is defined on the basis of soil characteristics, or of the landscape of which the soil is a part, that are important in land use but are not differentiating characteristics of the soil profile. Soil phases may include stoniness, slope, or degree of erosion.

Soil classifications by Marbut (2) include:

<u>Group I</u> - Soils in which mechanical transfer of fine-grained mineral material, clay and silt, from the upper part of the soil to the lower part, has taken place, producing a relatively light-textured surface soil and a relatively heavy-textured subsoil. Along with the mechanical transfer has been a chemical transfer of sesquioxides, alkalies, alkaline earths, and organic matter. Percent of iron and aluminum is low in surface soil. (Marbut terms this group as the PEDALFERS in a later publication.) HUMID SOILS.

<u>Group II</u> - Soils in which a mechanical transfer of fine-grained material from the upper part of the soil and its occurrence in the lower may or may not have taken place, but in which in the mature or fully developed soil, a layer of alkali, or

alkaline salts, usually calcareous, has occurred in some horizon which may be called B. (PEDOCALS) - ARID OR SEMI-ARID SOILS.

Russian soil scientists also gave a great deal of attention to soil classification and came out with two large segregations called the podsols and chernozems after large areas of characteristic soils in Russia. 1/

"Southwestern Range Ecology" says of these:

> In general, the Russian segregations of podsols and chernozems are applicable to large areas of soil in the United States. Podsols may be found in the region adjacent to the Great Lakes and in the New England States, that is, from northeastern Minnesota to northern New York and New England. Podsolic soils occur in areas that are well drained and undisturbed in the main by man or excessive erosion. The native vegetation was forests of hardwoods and conifers. Podsolic soils generally have not been recognized as occurring in the Southwest. Recently, however, the Soil Conservation Service has found soils of this group in the Cataline and Graham Mountains of Arizona. Future examination of our forest soils, especially in the spruce-fir type, will undoubtedly reveal other areas of podsolic soils as occurring throughout the higher elevations of the Southwest.

1/ Dr. Martin points out that under the U. S. system the Pedalfer and Pedocals are divided into a series of which the Podzol or podzolized soils are most typical of the Pedalfer and the cherozem of the Pedocal.

Chernozem soils are found exclusively under grassland vegetation. In the United States they reach their greatest development in the tall-grass plains of the central prairies. Other areas occur in southeastern Washington, northeastern Oregon, and northern Idaho. In the Southwest it is quite probable that they occur in many mountain park areas of Arizona and New Mexico. In the chernozem soils organic matter is disseminated throughout the entire soil profile since each year the roots of the grass die out. These soils are characterized by a deep dark brown to black A horizon grading out into a grayish to yellowish subsoil. Calcium carbonate may be disseminated throughout the subsoil and may occur as concretions or pellets. Precipitation generally varies from 18 to 28 inches per year.

According to the Soil Survey Division of the Bureau of Chemistry and Soils, the greater portion of the soils in the Southwest are grouped under names largely American in origin. Most of our Southwestern soils are included in the following soil groupings: reddish chestnut, brown, reddish brown, Shantung brown, gray desert, red desert, and lithosols or shallow soils.

Reddish chestnut soils are mostly found under shortgrass vegetation; however, in the sandier areas shinnery oak may predominate. They occur from southern Kansas, through

Oklahoma, eastern New Mexico, and Texas to the Gulf of Mexico. Although none have been reported from Arizona, it is possible some of these, including brown soils, occur under similar climate and vegetation. Surface soils are dark reddish brown which merges in the subsoils lighter or grayer color. Horizon A is friable and horizon B is heavier and tougher and highly calcareous in the lower portions.

The brown soils are quite similar in appearance to the reddish chestnut soils having brown surface soils which grade into subsoils underlain with gray or white calcareous layers. These soils are formed beneath shortgrasses, bunchgrasses, and shrubs. They commonly occur in the Western Great **Plain** (eastern New Mexico) and in scattered areas in the Intermountain Region and the Southwest.

Reddish-brown soils include large areas of the Southwest from western Texas to southern Arizona. They occur under low density, shortgrass or bunchgrass vegetation with scattered shrubs and small trees such as mesquite. Surface soils are reddish brown to red in color which fades in subsoils to a pink and even white color. Surface soils are of mellow consistency, subsoils are heavier, tougher, and very limy. These soils are fertile and form excellent farming land under irrigation.

Shantung brown soils exist under chaparral or thin forest cover or grassland with a few scattered trees and are largely confined to the mountain hills and valleys of southern and central California and central Arizona. Surface soils are brown, reddish-brown, or red, usually mellow or somewhat compact with redder colored subsoils which are heavier and tougher with but very little lime carbonate present.

Gray desert soils occupy vast areas of desert in the Intermountain region and are also found in the northern portions of Arizona and New Mexico. These soils are largely found under sagebrush and shadscale types of vegetation. Surface soils are usually light grayish brown or gray in color, low in organic materials. Subsoils are of lighter color and lime. These soils may contain excessively high concentrations of soluble salts, which im some areas may be too salty or alkaline to produce crops; however, many areas are fertile and highly productive under irrigation.

Red desert soils occur from Texas to southeastern California and include large portions of the arid Southwest. Surface soils are light-pinkish gray, reddish-brown, or red with lighter-colored subsoils which being only slightly leached are highly calcareous. Typical cover of vegetation is creosote-bush, paloverde, and cholla cactus.

Lithosols and shallow soils are typical of rough, stony land and rock outcrop with sparse vegetation. Extensive areas are found in western Arizona and the mountainous country of the Southwest. These soils vary tremendously, depending largely on the nature of the underlying rock. Many of these soils are highly calcareous.

It is indeed unfortunate that so many of the soils we are interested in are unclassified as to type and are lumped in the lithosol class. While these soils vary tremendously and are dependent largely on the nature of the underlying rock, they are the ones which influence stream flow or water yield. It will be necessary therefore to work out some system of classification for these. 1/

Physical Properties of Soils

Soils are formed from rock through the process of weathering. The abrasive effects of wind and running water, the force of rain and alternate heating and freezing are factors that cause chipping, cracking and gradual disintegration. The worn down rock fragments are gradually ground into smaller and smaller particles and the process of soil making continues with the accumulation of these small particles plus decaying organic matter. Chemical weathering also takes place through the formation of acids to form clays. This soil material, however, can hardly be called soil until it has assumed definite soil layer arrangement or horizons.

1/ Dr. Martin of the Southwestern Forest and Range Experiment Station suggests that such a classification might be based on geologic-vegetation correlations plus data on depth, organic matter, content, etc.

Soil testing up to date has been largely a laboratory job but since the management of soils must be on a pretty broad basis it is felt that even rough field determinations of important soil types may be of great value in indicating basic management needs and adjustments.

Many soil properties important to management can be readily tested in the field and at least comparative evaluations made with respect to soil texture, cohesion, structure, infiltration and absorption. All of the foregoing properties have a distinct bearing on land management and some of them at least may be recognized in the field and roughly classified and compared by a close examination of soil samples. See accompanying soil classification card, page 140, for testing the texture of soils. (Note: Dr. Martin of the Southwestern Forest and Range Experiment Station suggests that the usefulness of the soil classification card will be greatest at the extremes--stating that; "Most soils and more particularly the high organic mountain ones are fairly well aggregated so that the silts and clays will look like sands on the chart. The only way to get the actual size is to disperse the soil. This can be done in the palm of the hand if the soil is wetted. With a little experience on the laboratory-graded samples one can become quite expert at telling texture by the 'spit-feel' method." See page 44, Ecology Course.

Texture

Texture relates to the mechanical composition of soils and the size of soil particles. Loam, for example, is described as 30 to 50 percent sand, less than 20 percent clay and 30 to 50 percent silt. Sand is the heaviest of all soil material, weighing approximately 106 pounds per cu. ft. (dry) as compared to about 90 pounds for silt-loam material. Silt-loam is considerably lighter in weight than an equal volume of sand because there are more spaces in the finer material. Sandy soils however are usually called light soils and clay soils (fine) are termed heavy.

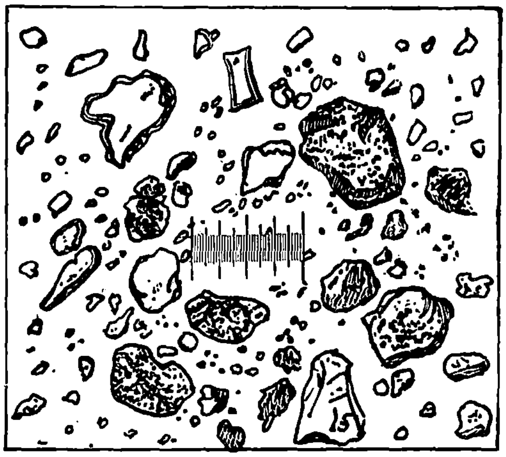


Figure 4. Highly magnified silt and sand. Dark colored particles are coated with colloidal material. Magnification of approximately 150 diameters brings out smallest graduation of scale, 2/1000 millimeter. Separates of less than 10 spaces diameter are silt.

Soil texture has a relationship to the rate of water percolation and the water holding capacity of soils and consequently to the amount of water available to plant life. Soil texture may also be indicative of soil development and soil losses. Well developed soils are usually made up of much finer material than are the younger undeveloped soils. This finer, lighter material however is in some respects more susceptible to wind and water erosion since it is more readily carried in suspension. Therefore, soils that have lost much of this fine material by erosion usually run a high percentage of coarse material when spread on the classification chart but often retain enough of the fine, dark colored material to identify them. Fine material characteristically on and near the surface is indicative of improving soil conditions while coarse material on top and finer material underneath may indicate loss of fine material by erosion.

Silt loams and clay loams are characteristically fine textured and have greater productive qualities than the coarse textured soils. Most soils of the United States, according to Weir, have a silt-loam texture, a small number are loams and then follow the fine sandy loams. Clay and fine sand probably dominate in the southwest. (Rough soil texture determinations and comparisons may be made in the field by the "spit-feel" method or with the aid of the soil classification card.)

Cohesion

Obviously there is little cohesion in coarse, gravelly soils and sands. Cohesion rapidly increases in the finer grained soils as a result of the water films around the fine grained particles, the

binding action of the usually present organic matter and the physical forces associated with colloidal matter which consists of very tiny clay particles the chemical composition of which may also be a factor since sodium clays are very sticky as compared to calcium clays. Cohesiveness or plasticity is usually associated with very fine soils, such as the clays, and can readily be tested by thoroughly wetting soils and pulling them apart with the hands. (Demonstrate cohesiveness by wetting masses of different soils and observing cohesiveness.) Loose granular, mineral soils offer little resistance to "lifting out" a handful of the saturated soil but this becomes increasingly difficult as soils with increasing clay content are tested. Although there is some doubt as to the value of the soil cohesion or resistance test in estimating the general erodibility of soils, the most significant factor of which is the readiness with which particles go into suspension in water, still there is reason to believe that non-cohesive soils, especially if standing on a slope, have a tendency to erode much more rapidly under the action of water than cohesive soils. Also non-cohesive soils would be more subject to wind and gravity erosion just as sand flows in an hour-glass. Cohesiveness is generally associated with the amount of clay in soils and is considered indicative of certain types of erosion resistance.

This resistance is further indicated by experiments carried out on the Boise River Watershed (12) where it was found:

"That origin of the soil has played some part in the degree or erosion is shown by the fact that 63 percent of the areas having granitic soil, containing a high percentage of new

gritty material deficient in binding properties, were eroded, whereas only 49 percent of the areas having soil chiefly derived from lava or porphyry showed erosion. Furthermore, gullying was found only on areas with granitic soils.

"Coarseness is an outstanding characteristic of the soils on the area studied. Mechanically analyzed, representative samples have an average clay content of 9 percent and an average silt content of only 10 percent. Coarser material makes up the remainder, the average sand content being 50 percent with an additional 31 percent made up of particles in excess of 2 mm in diameter.

"Segregation of the data by soil-texture classes, together with the degree of erosion found to accompany these soil conditions, indicates that texture exerts an important influence upon erosion. As shown in the following tabulation, erosion, both sheet and gully, was less than half as prevalent on the fine as compared with the coarse soils.

"Distribution of areas in each erosion class according to soil texture.

Texture class	No erosion	Sheet erosion	Shallow-gully erosion	Deep-gully erosion	All areas	
	Number	Number	Number	Number	Number	Percent
Fine	24	10	0	2	36	3.4
Medium	194	147	14	3	358	34.3
Coarse	157	406	69	18	650	62.3
Total	375	563	83	23	1,044	100.0 "

Structure

Soil structure relates to the manner in which small particles or soil separates group themselves into crumbs or lumps.

This results through the action of water films in cementing substances, organic matter and colloidal materials. Common soil structures are therefore described as: single grain, as in sand; granular, crummy as in crumbly silt loams; columnar, prismatic, etc.

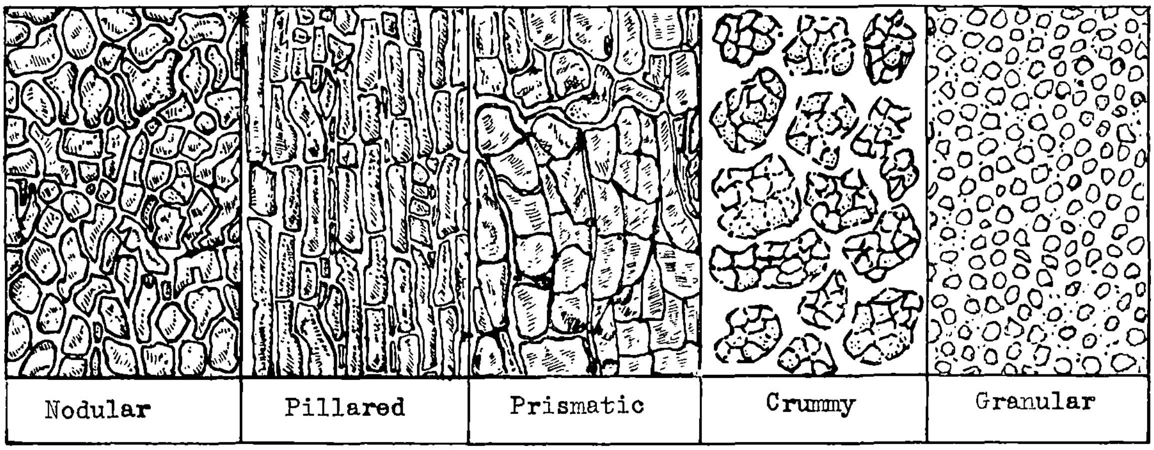


Figure 5 - Soil structures

Soil structure may be readily studied in the field by examining gully banks, and road cuts or making small trenches up to 8 or 10 inches in depth and width so that the undisturbed soil profile of the banks may be closely observed. (Demonstrate by pointing out structure in gully banks.)

Soil structure as Weir points out is very important in management as it relates to the development and maintenance of a physical soil condition that favors plant growth. Soil structure may be readily destroyed through improper soil management. In this connection it will be apparent that when heavy soils become plastic by water absorption it is easy to destroy their natural structure by compaction of the fine textured materials through trampling. On drying, a puddled soil material becomes very hard and compact. Surface run-off is accelerated and water that formerly penetrated into the soil and

was available for plant life quickly runs off into gullies and is lost in some sandy dry wash. (Demonstrate puddled compaction by actual tests or pointing out hardened soil of road ruts, or cow tracks.)

Granulation of soils is in effect the opposite of compaction. Alternate wetting and drying or alternate freezing and thawing of soils will correct a puddled condition. Water is the principal agent and acts by pushing the soil particles apart (ice crystals are particularly effective in this way) causing clods or dense masses to crumble. (Demonstrate by briefly soaking a hardened clod in water and then setting it down on the dry ground - often it will undergo a certain amount of crumbling while you watch.)

Infiltration and Absorption

Percolation of water into soil and the rate of infiltration varies greatly with soil conditions and different soil types. The over-all water holding capacity of soil types is also governed to some extent by the depth of the porous upper soil masses. When rock or impervious soil strata occur close to the surface the water holding capacity is accordingly limited.

Soils in place are usually very porous. About 40 percent of the volume of dry, compact sand and about 60 percent of dry, compact muck is air. Weir points out the importance of porosity stating that under optimum moisture condition for plant growth, about 20 percent of a given volume of fine-sandy-loam, silt-loam, or clay-loam material consists of pore or air spaces. This porosity importantly affects soil productivity because of its effect on biological activities,

exchange of carbon dioxide and oxygen, chemical reactions and biochemical changes that are fundamental in plant nutrition.

Absorption also is a well known property of soils and is of vital importance as it relates to the retention of water for plant use. The water holding capacity and absorptive qualities of soils are not readily demonstrated by field tests although the <u>infiltration rate</u> of different soils or the same soil under different conditions such as loose or compacted, may be compared by cutting both ends out of identical cans, say the ordinary No. 2 can, and up-ending one on a sodded area and the other on a nearby denuded area. They should be firmly pressed into the surface so that leaks do not occur at that point and then filled with water and the infiltration time observed. The infiltration rate of different soils may be thus timed or the infiltration rate of the same soil may be timed under different conditions such as: well vegetated, partly denuded, denuded, puddled, etc.

<u>Color</u>

Color of soils is important because of its indication of soil values or productivity. Color usually comes from organic material although in some instances color results from the presence of coloring substances like, iron oxides and manganese. The real significance of color relates to its humus content and in ordinary soils may be readily observed in banks or cuts where the darker colors of the upper profile or topsoils are usually in marked contrast to the lighter colors of the subsoils. The presence of organic material in soils is very favorable to absorption and water holding capacity.

Organic matter not only furnishes subsistence to soil bacteria but also changes the physical structure of the soil and increases its ability to absorb and retain water. This organic matter also makes the soil loose and porous, providing better soil aeriation. Although most mineral soils are said to contain less than 5% organic matter its significance lies in the fact that all of the nitrogen and sulphur are held in the organic combination.

Soil porosity usually refers to the percentage of the soil volume unoccupied by solid particles. Organic matter contains very little mineral food--its greatest effect relating to water penetration and the maintenance of soil structure. In general, well developed, undisturbed soils are considered to have three distinct layers differing in color and texture. These are called, horizons A, B, and C. To all intents and purposes the A-horizon, or top-soil and the B-horizon or subsoil make up the soil mass with which we are concerned, there frequently being no very recognizable distinction between the lower part of the subsoil B-horizon and the substratum or C-horizon. In forest soils the upper layer or A-horizon is likely to be dark colored--derived from organic matter, friable, coarse textured and porous. The B-horizon reflects an accumulation of fine material brought down from the upper layers by the infiltration of water, intermixed with coarser materials from below. The C-horizon is the weathered rock, sand or clay derived from the parent formation.

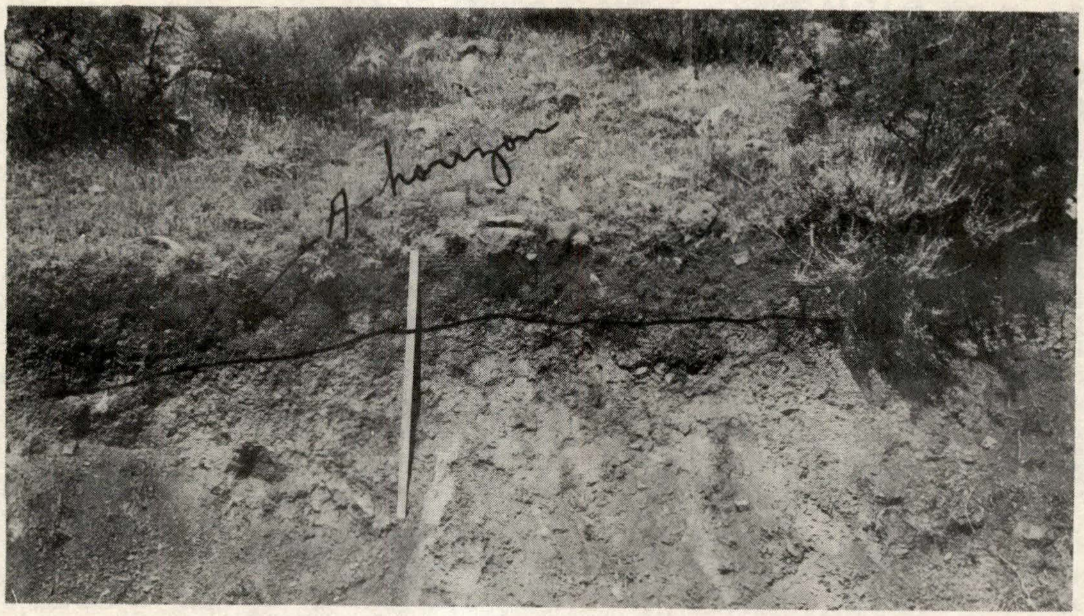


Fig. 6 - Soil Coloring also indicates horizon development.

The presence of a distinct A and B horizon therefore indicates a soil development of some consequence. It indicates sufficient organic matter in the soil to maintain necessary soil bacteria and the presence of other elements essential to plant life. This return of plant material through decay and the weathering, leaching and chemical changes of the rock particles has continued endlessly through the centuries that are required to build the deep, productive soil types now common to most of our national forest watersheds.

A broad classification of southwestern soils is seen on page 37.

Table 1-General Characteristics of Soils and Their Environs 1/

ZONAL

Group	Zonal soils	Profile	Native vegetation	Climate	Natural drainage	Soil-development processes	Productivity (crop plants)	Present use
°Pedocal	Desert	Light-gray or light brownish-gray, low in organic matter, closely underlain by calcareous material.	Scattered shrubby desert plants.	Temperate to cool; arid.	Good to imperfect.	Calcification	Medium to high, if irrigated.	enterprises. Grazing in large units. Intensively farmed in small units where irrigated. Crops specialized in many places.
	Red Desert	Light reddish-brown surface soil, brownish-red or red heavier subsoil closely underlain by calcareous material.	Desert plants, mostly shrubs.	Warm-temperate to hot; arid.	do	do	do	Do.
	Sierozem	Pale grayish soil grading into calcareous material at a depth of 1 foot or less.	Desert plants, scattered short grass, and scattered brush.	Temperate to cool; arid.	do	do	do	Do.
	Brown	Brown soil grading into a whitish calcareous horizon 1 to 3 feet from surface.	Short-grass and bunch-grass prairie.	Temperate to cool; arid to semiarid.	Good	do	High, if irrigated	Large farms of small grain (if unirrigated). Ranching in large units.
	Reddish Brown	Reddish-brown soil grading into red or dull-red heavier subsoil and then into whitish calcareous horizon, either cemented or soft.	Tall bunch grass ~~and shrub growth~~ Curley Mesquite° Grama°	Temperate to hot; arid to semiarid.	do	do	Moderate to high, if irrigated. Not suited to dry farming. Grazing good.	Grazing in large units. Small specialized farms where irrigated.
	Chestnut	Dark-brown friable and platy soil over brown prismatic soil with lime accumulation at a depth of 1½ to 4½ feet.	Mixed tall- and short-grass prairie.	Temperate to cool; semiarid.	do	do	Medium. High where irrigated.	Cereal grains, especially wheat and grain sorghums throughout the world. Excellent grazing in large units.
	Reddish Chestnut.	Dark reddish-brown cast in surface soil. Heavier and reddish-brown or red sandy clay below. Lime accumulation at a depth of 2 feet or more.	Mixed grasses and shrubs.	Warm-temperate to hot; semiarid.	do	do	do	Cereal grains and cotton. Excellent grazing in large units.
	Chernozem	Black or very dark grayish-brown friable soil to a depth ranging up to 3 or 4 feet grading through lighter color to whitish lime accumulation.	Tall- and mixed-grass prairie.	Temperate to cool; subhumid.	do	do	Medium to high. High to very high where irrigated.	Small grains and corn in moderate-sized or large units.
	Prairie	Very dark-brown or grayish-brown soil grading through brown to lighter colored parent material at a depth of 2 to 5 feet.	Tall-grass prairie	Temperate to cool-temperate, humid.	do	Calcification with weak podzolization.	High	Medium to small farm units. General farming, with emphasis on corn, hogs, and cattle.
	Reddish Prairie	Dark-brown or reddish-brown soil grading through reddish-brown heavier subsoil to parent material. Moderately acid.	Tall- and mixed-grass prairie.	Warm-temperate, humid to subhumid. Possibly some tropical conditions.	do	do	Medium to high	Wheat, oats, corn, cotton, hay, and forage crops.
°Pedalfer	Degraded Chernozem.	Nearly black A, somewhat bleached grayish A_2, incipient heavy B, and vestiges of lime accumulation in deep layers.	Forest encroaching on tall-grass prairie.	Temperate and cool; subhumid to humid.	do	Calcification followed by podzolization.	Medium to high. Low where strongly degraded.	Agriculture intermediate between Chernozem and Podzol. Of little importance in the United States.
	Noncalcic Brown (Shantung Brown).	Brown or light-brown friable soil over pale reddish-brown or dull-red B horizon.	Mostly deciduous forest of thin stand with brush and grasses.	Temperate or warm-temperate; wet-dry, subhumid to semiarid.	do	Weak podzolization and some calcification.	Medium. High were irrigated.	Grazing, dry farming with small grains, specialized irrigated crops including fruit .
	Podzol	A few inches of leaf mat and acid humus, a very thin dark gray A_1 horizon, a whitish-gray A_2 a few inches thick, a dark or coffee-brown B_1 horizon, and a yellowish-brown B^3. Strongly acid	Coniferous, or mixed coniferous and deciduous forest.	Cool-temperate, except in certain places where the climate is temperate; humid.	do	Podzolization	Usually low. Medium under good practices	Small [illegible] istence farms [illegible] luding dairy [illegible] Wood lots and [illegible] asture importa[illegible]

1/ From the 1938 year book separate No. 1663 by Baldwin, Kellog and Thorp.
°Local additions to original chart.

1938

Soil Classificatic

997

Influences of Soil ~~and~~ on Run-off

Soil conditions directly affect both surface and ground water run-off. To a large extent the amount of water absorbed into the ground water reservoir, depends upon the intensity of storms, slope and surface, the porosity of the upper soil layers and the vegetative cover.

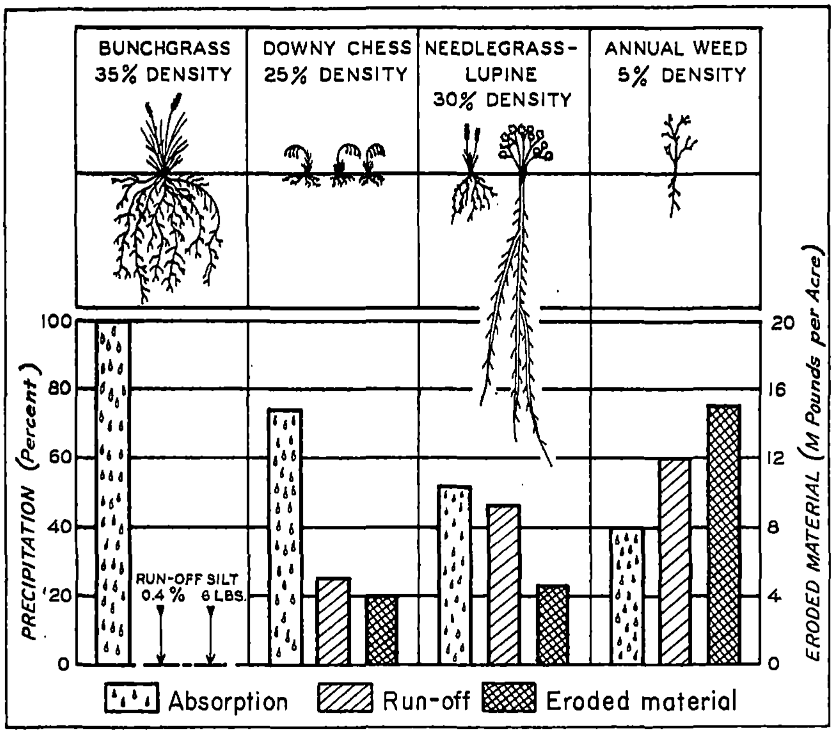


FIGURE 7.-THE MOST DESIRABLE FORAGE PLANTS ARE COMMONLY THE BEST WATERSHED PROTECTORS.

Run-off and erosion from rainfall are negligible where the bunchgrasses predominate - the highly palatable virgin-range cover characteristic of south-central Idaho. Both run-off and erosion are very pronounced where other plants have succeeded bunchgrass because of overgrazing. The greatest percent of run-off and the largest amount of eroded material come from annual weed cover - a plant cover which is an infallible expression of over utilization. A many-branched, fibrous root system is an important factor in retarding soil removal and aiding absorption.

FROM WESTERN RANGE

Naturally the greater the intensity of the storm and the longer its duration the more it will exceed the capacity of soils to absorb it. It is also apparent that the rate of surface run-off is accelerated in accordance with increased slope and smooth surfaces. In this connection it should be pointed out that the eroding power of water is due not only to its motion, which in turn is caused by the force of gravity, but the rate of erosion is largely determined by the rate of motion of the water or its velocity. It has been

shown that every time a land slope is increased four times, the velocity of water flowing over it is almost doubled. When the velocity is doubled, the erosive or cutting capacity is increased more than four times. This has special significance in determining proper grazing utilization on slopes.

In connection with ground water storage a recent publication (1) states:

> If the outer surface of the earth were a solid and impervious mass a torrent would rush from each watershed after every heavy rain. Floods, under such conditions, would be of such magnitude and such frequent occurrence as to prevent the establishment of land life. The earth's surface, however, is a relatively porous body capable of absorbing and holding a tremendous quantity of water.
>
> The surface mantle of the earth is commonly divided into two zones with reference to how and where water is held. This is illustrated in figure 1. These are the zones of aeration and the zone of saturation. The latter (ground-water supply) will be discussed later. The zone of aeration, which is the uppermost of the two, is divided into three principal parts: the belt of soil water, the intermediate belt, and the capillary fringe. The belt of soil water lies nearest the surface and moisture may be lost from it through transpiration by plants, or through evaporation after rising to the surface by capillary action.

The capillary fringe is the zone that lies immediately above the water table and contains water drawn up from the ground water by capillary action. Between these lies the intermediate belt, its thickness depending, of course, on the depth to the water table. An intermediate belt does not exist where the water table is sufficiently close to the surface to cause contact between the capillary fringe and the belt of soil water.

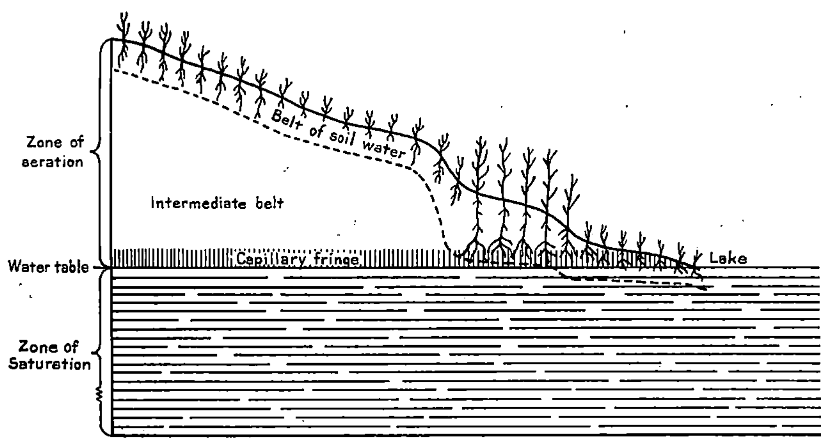


FIGURE 8.-Diagrammatic illustration of zones and belts of soil and ground water.
(U.S.D.A. Misc. Publication No. 397)

The water to be found in the zone of aeration is usually referred to as suspended sub-surface water or vados water. This is subdivided into soil water, intermediate vadose water, and fringe water. All suspended sub-surface water is held by molecular attraction and when this attraction is less than the pull of gravity the water moves downward into the next lower belt until finally it reaches the water table.

The depth of the soil water belt is determined by soil characteristics and the type of vegetal cover. The thickness of the capillary fringe is determined by rock or soil characteristics.

With only rare exceptions all forms of underground water are supplied downward from the surface. Hence the quantity of underground water is dependent on the quantity of precipitation and the infiltration capacity of the surface soil and on percolation through the underlying strata. Although the ground-water phases of land storage are very important in the economy of water, this publication deals chiefly with the soil as a reservoir for water, meaning the entire zone of aeration, pointing out those factors which will increase infiltration and its water holding capacity. The difference between the moisture content of the zone of aeration at the beginning of heavy or prolonged rainfall and nearly complete saturation of this zone is available as an equalizing reservoir for the retardation of water flow, provided the conditions of cover, soil, and other surface factors are conducive to maximum absorption and infiltration and the underlying strata are conducive to maximum percolation.

Where water passes over the surface of the soil rapidly there is less opportunity for its infiltration into the soil even where soils are in a comparatively receptive condition. Coarse, loose or sandy soils

infiltrate water much more rapidly than clay soils. R. E. Horton (3) in his paper on "Surface Runoff Control" includes the following comments on infiltration:

> Consider first a bare, dry soil, baked or compacted, and, in the case of soils containing colloids, with the surface sun-checked. Under these conditions different types of soil, ranging from fine sands to heavy clays, may have initially about the same infiltration capacity. In each case, when rain begins, infiltration capacity decreases, although in case of sand containing no colloids, the decrease is relatively slight. In case of loam the infiltration capacity decreases during rain owing to the swelling of colloids and the consequent closing of sun checks and other perforation, and if rain continues long enough the infiltration capacity reaches a minimum value, at which it remains until rain ends. As the soil dries out, its infiltration capacity increases, reaching a maximum usually in the course of 2 or 3 days. For heavy clay soils a similar course is followed but the minimum reached is much lower and may, in fact, be zero or near zero.
>
> There is also a variation of infiltration capacity for the same type of soil with different types of surface or cover. If the soil is initially thoroughly wetted by previous rains it will already be at its minimum infiltration capacity, which will continue unchanged

to the end of the rain, so that a few days after a heavy rainstorm the infiltration capacity will be restored to a normal maximum value much higher than when the rain began.

If the soil was bare, dry, and uncultivated, the infiltration capacity of the surface soil will fall during rain to the same minimum as for the soil initially wetted, and will follow the same course of recovery after rain ends. In this case the initial and final infiltration capacities may be about the same. If the soil was freshly cultivated so that the surface was loose, its initial infiltration capacity may be much higher than in the preceding case, but in this case the capacity will decrease very rapidly at the beginning of rain, because of rain-packing, and thereafter will decrease to the same minimum as before, but upon drying out it will return to the value for packed soil, much less than the initial value.

If the soil is covered with a good grass sod and is initially baked and sun-checked, then the initial infiltration capacity will usually be considerably above that for a bare, dry, baked soil but may be considerably below that for a freshly cultivated soil.

The high infiltration capacity of sodded soils is apparently due partly to the presence of considerable numbers of relatively large openings into the soil surface. Sun checks, openings left by decaying roots, earthworm and other perforations near the surface, are destroyed by cultivation although they may still persist at greater depths. The importance of the presence of these larger openings in providing for the ingress of water and the escape of air is illustrated by a simple hydraulic calculation, which shows that a single earthworm perforation 0.1 inch in diameter will permit as much water to enter the soil, or as much air to escape, as could flow through 1,000,000 interstitial openings between soil grains of a fine sandy soil. Reduction of surface erosion and the consequent prevention of the closing of the larger soil surface openings by inwashing of fine materials is certainly an important factor in preventing the abrupt reduction of infiltration capacity at the beginning of rain which occurs on newly cultivated bare soils as a result of rain packing.

In long rains, infiltration capacity of the subsoil rather than that of the soil surface may become the controlling factor. Much remains to be learned about infiltration through the subsoil below the depth of cultivation. It is certain, however, that the infiltration

> capacity of the subsoil is much less variable than that of the surface soil and if the soil profile is homogeneous, the infiltration capacity of the subsoil is usually equal to or greater than the minimum for the surface soil but may be less than the maximum. If the lower soil horizons are more dense than the surface, then, in long rains, the infiltration capacity may be reduced to that of the subsoil, or below the natural minimum of the topsoil.
>
> High infiltration capacity during short rains commonly prevails for all types of soil when initially dry. To be effective in controlling run-off in prolonged rains as produce maximum floods, a high minimum infiltration capacity is necessary.

Horton concludes with the observation that infiltration capacity is the most important factor in controlling surface run-off. By way of illustration he points out that the maximum run-off intensity decreases quite uniformly as infiltration capacity increases and will, of course, become zero if the infiltration capacity equal the rain intensity. He further states that:

> The effect of increased infiltration capacity on surface run-off differs from the effect of the other factors - slope and length of overland flow - in one important respect; an increase of infiltration capacity decreases both surface run-off and total run-off in about the same pro-

portion in long and short rains. Surface run-off intensity cannot exceed the supply rate or difference between rain intensity and infiltration capacity, and since total run-off is nearly proportional to the total supply, it is evident that a change in infiltration capacity produces a change in maximum run-off intensity, total run-off and total infiltration which is in all cases nearly proportional to the change in supply rate.

Data developed at the Southwestern Forest and Range Experiment Station indicate a need for placing more and more emphasis on surface soil condition as it influences water infiltration. "Falling raindrops reaching the surface of unprotected soils disperse, sort, pack and puddle the soil particles into a very thin (2-3 mm) layer which resists penetration and greatly increases run-off. The fine particles are brought into suspension and leave in the run-off. This rainfall induced surface layer is not developed and intensified through a series of storms with in-between drying, but is formed even on freshly cultivated soils almost at the beginning of rainfall. According to Duley and Russel (Nebraska): "this crusting as it affects run-off and decreases infiltration is the most important single factor in this regard, indeed, is more important than slope, texture, structure or soil type combined.

"This has been our experience in tests with a rain-fall-simulator apparatus. Using a 2" per hour rain as standard, the following results were obtained on a sand and a clay when the surface soil was protected with a mulch or unprotected.

	Runoff in percent	
	Mulched	Unmulched
Pima silty clay loam	22	39
Continental gravelly sandy loam	13	81

The difference would probably have been even more striking had plots been available with good grass cover."

Influence of Cover on Soil Temperature

The presence, type and abundance of vegetation on the surface has long been recognized as a major factor in influencing soil temperatures which activate chemical and biological changes in the soil. Nitrification, for example, doesn't take place until soil temperatures reach about 40 degrees and is most active at about 80 to 90 degrees. Seed germination, though varying widely, also depends on soil temperatures. In this connection, soil color and slope are also pointed out as important influencing factors, the dark colored soils absorbing more heat than the light colored ones, while exposure or slopes may often make upwards of 20 degrees difference. Bare soils warm up more quickly and cool off more rapidly than vegetated slopes while winter frosts and freezes penetrate bare soils more deeply.

Chapter III - Vegetation

Characteristic vegetation of the basins and watersheds of Region 3 varies from the southern desert shrub types of lower elevations to arctic-alpine meadows above timber line. Occurring between these elevations are the semi-desert grassland and short grass types, chaparral, northern desert shrub, woodland and the coniferous timberlands of pine, spruce and fir. It is in these dense timber types of the high mountains that the snows accumulate to form the source of perennial streams that furnish most of the irrigation water for the large reclamation projects as well as the water for the cities and towns dependent on surface supplies.

Protective Features

Vegetation furnishes the magic mantle of protection to soil surface. Most important of all vegetation prevents rain-packing of the surface, resists erosion, slows down runoff thus promoting increased infiltration of water into the soil, and builds up soil character and fertility. Vegetation is as necessary to soil as soil is to vegetation and soils quickly reflect the effects of cover depletion. These effects are noted in accelerated speed of runoff, in loss of root binding power and consequent accelerated movement of soil, in increased soil compaction and reduced infiltration capacity.

Fig. 9 - Effective Watershed Cover, Lincoln N. F.

The whole effect of cover on surface and ground water flow is best described by quoting further from R. E. Horton's paper (3)

> It is now well established that a good sod or grass cover is the most effective natural means of controlling surface runoff and preventing soil erosion. The beneficial effect seems to be more closely related to the density, that is, number of plant stems per unit area, than to size of the plants, While other things are involved in case of wooded land, the trees of a forest may have less effect in controlling runoff than the grass under the trees.

Reduction of surface erosion by grass cover has often been attributed to the binding effect of grass roots. Kramer and Weaver (4) have shown that the effectiveness of grass cover is more largely due to the aerial parts of the plant than to the roots. The way in which grass cover operates to reduce the intensity and volume of surface runoff does not seem to have been clearly or fully explained. Surface hydrology of grassland and forest differs so much from that of bare soil or soil with wide-spaced row crops that it is difficult to make general comparisons. Broadly it appears that the beneficial effects of a dense grass cover in reducing runoff intensity and volume results mainly from:

1. An increase in surface detention by capillary storage in wedge-shaped spaces between grass leaves or leaves and stems.

2. Better sustained and probably higher infiltration capacity and prevention of closing of openings in the soil surface by inwashing of fine material, as described by Lowdermilk.

3. A different type of overland flow from that prevailing on other soil surfaces. This may be designated as 'sub-divided flow.'

He (3) further explains "sub-divided flow" by pointing out that...

Increased resistance to flow over sod is therefore due mainly to increased friction surface. Alternate

expansion and contraction of the water filaments in the tortuous passage-ways through the grass also plays a part. This partially accounts for the observed limitation or absence of surface erosion on sodded ground. At the same time, reduction of velocity carries with it a corresponding increase of the average depth of surface detention and a consequent decrease of surface runoff.

In explaining the relationship of surface control to plant growth and ground water, he summarizes by saying:

> Increased infiltration rebounds of necessity either to the soil-moisture zone or to ground-water storage. Vegetation has the first chance but if a given increment of infiltration is not used by plants, an equal amount of accretion to ground-water storage will take place subsequently.

Leaching of the Soil

Fear is sometimes expressed that increasing infiltration may result in serious loss of soil values through leaching but he largely dispels such fears by reasoning that: (3)

> All methods available for reducing runoff depend, and must necessarily depend, on some means of increasing the infiltration capacity, providing a longer-sustained infiltration capacity above the minimum, or by increasing surface detention and with it the duration of infiltration at capacity rate. It has been suggested that any method

which increases the infiltration will also increase the loss of nutrient material from the soil by leaching. This is practically never destroyed by leaching, probably for the reason that the combined action of sun, air, and rain on newly exposed material converts it into a form available for plant use, that is, matures the soil as fast as or faster than previously available nutrient material is removed by leaching.

Surface Runoff Control as Drought Insurance

Water in the soil available for plant use is that lying between the wilting point as a minimum and the field-moisture capacity of the soil as a maximum. When water enters the soil by infiltration it is all held in the soil above the water table until the soil moisture is built up to equality with the field-moisture capacity in the entire soil column from the soil surface down to the water table. Thereafter all additional infiltration goes directly into the ground-water reservoir. Excepting as it may be removed by evaporation or by transpiration through plants, soil moisture remains permanently within the soil. Ground water, on the other hand, is gradually exhausted by outflowto streams, lakes or oceans, at a rate nearly or precisely proportional to the volume of ground water remaining in the aquifer. During a prolonged drought, both

soil moisture and ground water become severely depleted. When rain comes the infiltration all goes to replenish soil moisture until this is restored to field-moisture capacity. This may require months although it is usually attained within a single annual hydrologic cycle.

..... It has been shown that soil moisture is replenished mostly from shorter, more frequent rains, while the ground-water reservoir is rarely replenished except from long-continued, heavy, infrequent rains, and would not be replenished even from these excepting for the reduction of field-moisture deficiency by shorter, more frequent rains. It has been shown that there are various ways in which infiltration can be increased in conjunction with surface runoff control. Any increase of total infiltration will necessarily result in reduction in the duration and intensity of physiologic droughts by increasing the soil-moisture content when drought begins and reducing the time required to restore soil-moisture to its field capacity when rains come. Likewise, there will usually be more ground water in storage when drought begins and a shorter lag interval in restoring phraetic water to normal after physiologic drought ends.

Surface runoff can be controlled or reduced by (a) increasing the length of overland flow, (b) decreasing the surface slope, (c) increasing depression storage, (d) increasing the infiltration capacity of the soil.

Soil Stabilization

The effects of plant cover on soil stabilization have been strikingly demonstrated in the Region by work at the Sierra Ancha Experimental Forest branch of the Southwestern Forest and Range Experiment Station (unpublished data). Results of those studies are summarized as follows:

Table 2

(Storm of August 5 - 6, 1939 totalling 4.02 inches)

Soil Sample Selections from the Tonto National Forest

Soil-type area	Surface run-off (Inches)		Soil erosion (Cubic inches)	
	Bare	Vegetated	Bare	Vegetated
Volcanic or black malpais (NW of Mt. Ord)	2.08	1.29	190.5	27.0
Gray schist (North of Mt. Ord)	3.45	2.56	68.5	22.0
Stony conglomerate (Roosevelt Lake Basin)	2.52	1.00	140.0	4.5
Red shale (Colcord Mt.)	3.15	.77	186.0	1.5
Sandstone (Juniper Flat)	2.48	1.06	165.5	8.5
Diabase (Sierra Ancha Bench)	2.02	1.11	64.0	7.0
Rocky quartzite (Sierra Ancha Bench)	2.27	1.03	49.5	1.0
Total	17.97	8.82	864.0	71.5
Average	2.57	1.26	123.4	10.2

Soil losses are far greater from bare areas than from vegetated areas on all seven soil types.

That the litter, resulting from a good cover of grass, forest, or shrubs is of almost as much importance as the vegetation itself in retarding runoff, is well described in Senate Document No. 12 - A National Plan for American Forestry. (5)

> Forest litter is the layer of fallen leaves or needles, of dead branches, down trunks, and other vegetable remains, which in varying depth is found under the crowns of trees and brush species in every temperate-zone forest. Through the gradual processes of decay and chemical change, and through the agency of animals which trample or otherwise disturb the surface of the ground, this litter is disintegrated into humus. Percolating water then carries the fine particles of humus, into the soil, where they are further broken down into nitrogenous products by bacteria and other organisms.
>
> Forest litter exerts its influence in several ways. First and most important, it contributes to the humus content of the soil. It is an axiom in agriculture that humus, or organic matter, makes a heavy soil lighter, and a light soil heavier, by causing the soil particles to form crumbs. A crumb structure gives the maximum room for air and water, both vital to plant growth. How powerful an effect organic matter,

although an unimportant fraction by weight in most soils, has on the water-holding capacity of the soil is illustrated by analysis in Table 3, made by George Stewart of a granitic sand supporting ponderosa pine in Idaho. About 200 samples of the soil were taken to a depth of 4 inches, from openings, some large and some small, in a virgin stand. The condition of the vegetation refers to its value primarily as forage, and the deterioration is the result of grazing.

Table 3
Analysis of Granitic Sand Soil Under a Ponderosa Pine Stand in Idaho

Condition of Vegetation	Organic Matter*	Water-holding Capacity*
	Percent	Percent
Good (nearly original condition)..........	10.5	81
Intermediate (considerable deterioration)	4.8	55
Poor (bad deterioration, soil usually gullied)..........................	2.4	44

*In percentage of dry weight of soil.

The ability of this soil to absorb water was nearly halved by its loss of a very small quantity of organic matter. Inasmuch as the soil of any watershed is the great underground reservoir replenished from time to time by precipitation, but at all times draining into the streams, its absorptive capacity is the great factor in sustained streamflow. Humus and the decaying roots of plants enormously increase this capacity.

A second major influence of forest litter is its promotion of water percolation. If a soil is extremely shallow, or if precipitation is unable to percolate into it rapidly, runoff must take place over the surface from any but the lightest storms. If rain falls upon bare soil it becomes muddied and carries fine material in suspension downward into the minute interstices between the soil particles. How promptly and completely muddy water will plug these pores and slow the rate of percolation has been demonstrated by Lowdermilk (6). After establishing, over a period consisting of parts of 7 days, the rate at which clear water percolated through columns of soil, he introduced sediment of less than 2 percent by weight into the water; within 6 hours the rate of percolation fell to 10 percent of what it had been. Moreover, the effect was permanent, as a return to the use of clear water did not restore the original rate. A good forest litter keeps the rain from becoming muddied when it hits the earth and so decreases runoff; in the absence of litter, surface runoff is enormously increased.

The following table is also interesting in showing effect of litter and herbaceous cover on infiltration, percolation, and soil erosion and as indicating the extent to which surface litter retards surface runoff but builds up ground water delivery via the percolation route. Following are results obtained from lysimeter installations at the Forest Service Sierra Ancha Experimental Forest station in Arizona:

Table 4

Data from Southwestern Forest and Range Experiment Station

Period	Rainfall in Inches	Surface Runoff in Inches: Lysimeter #1	Surface Runoff in Inches: Lysimeter #2	Infiltration of Precipitation in Inches: No. 1	Infiltration of Precipitation in Inches: No. 2	Percolation in Inches: Lysimeter #1	Percolation in Inches: Lysimeter #2
	Before litter was placed on lysimeter #2						
April 1 to Sept. 30, 1939	5.43	0.42	0.36	5.01	5.07	0	0
Oct. 1, 1939 to Mar. 31, 1940	5.09	0.22	0.17	4.87	4.92	0	0
April 1 to Sept. 30, 1940	8.69	1.13	1.09	7.56	7.60	0	0
Totals	19.21	1.77	1.62	17.44	17.59	0	0
	After litter was placed on lysimeter #2						
Oct. 1, 1940 to Mar. 31, 1941	22.96	6.06	2.50	16.90	20.46	4.88	7.69
April 1 to Sept. 30, 1941	7.65	1.73	0.90	5.92	6.75	0.01	0.10
Totals	30.61	7.79	3.40	22.82	27.21	4.89	7.79

It should be noted that during the first period with only 19.21 inches of rain there was no ground water percolation on either lysimeter although the surface runoff of No. 1 slightly exceeded that of No. 2.

During the second period the precipitation greatly increased and litter was placed on lysimeter No. 2. As a result of the surface protection afforded by the litter, surface runoff on No. 2 was less than half that of lysimeter No. 1, although the net water yield of Lysimeter No. 2 when adding surface run-off and percolated water together equalled 90% of the net yield from No. 1 with its high surface runoff. This is convincing evidence of the value of surface cover in retarding destructive surface runoff without materially altering net water yield.

Chapter IV - Watershed Management

Objectives

The improvement and maintenance of the vegetated watersheds as the source of water for domestic uses, irrigation, power and industry and as the only large scale natural means of runoff control essential to the regulation of streamflow and the prevention of floods.

Objectives in watershed management may include more specifically:

(1) The maintenance of forests or other types of natural vegetative cover on the slopes of the watersheds and the protection, proper use and management of the soil and vegetative resource.

(2) The avoidance of excessive grazing, timber cutting or other forms of overuse.

(3) The improvement of tillage and cropping methods to reduce erosion from cultivated lands.

(4) The improvement of road location and drainage disposal.

The Federal government should take the leadership in bringing about proper watershed practices on its own lands. Government might also wisely continue the development of cooperative programs to induce better management and corrective measures on private lands. Basic land use adjustments and other resource management proposals essential to the improvement of watersheds deserve first consideration. Along these lines Bowman (10) points out that we must:

> therefore, turn to watershed management through control of the vegetation, the forests, and the range grasses. By

'control' we mean the elimination of abuse and dependence upon 'the generally inexpensive measures of nature rather than---the costly constructions of mankind.'

Experimental plot studies clearly show that it is possible to increase the amount and rate of surface-water absorption by favoring the fibrous-rooted plants, the roots supplying additional and highly effective channels of penetration. Once water is absorbed, its time of delivery is delayed (in contrast to 'flash' or flood runoff), the rate of delivery is slowed down (with reduction of waste), and the period of delivery is prolonged (when crops need it most). These are the effects we have in mind when we say that the water table should be progressively raised rather than progressively lowered, as at present through gullying following overgrazing or through improper agricultural practice. A further beneficial effect would be to restore the soil to an earlier and better condition which, in turn, would have a reciprocal effect upon the vegetation. The silting of ditches and the filling of reservoirs with unwanted and eventually destructive sediments would also be greatly diminished.

When erosion of the soil takes place at a rate that markedly exceeds the building process, there is set up not mere erosion of so many inches per unit of time but the differential erosion of the separate soil particles or chemical constituents. Colloidal material, together

with nitrogen and organic matter, go first, leaving coarser material in place so that the fundamental structure of a soil is changed through excessive loss of the surface material. The effect is not merely the loss of an arithmetical surface fraction of a homogeneous mass. This structural change means not only loss of fertility but loss of water holding capacity. Once this fundamental change for the worse is really understood, it will be clear that from social and economic standpoints as well as from the scientific standpoint the loss of fertile soil through wrong tillage methods or the destruction of the vegetation (that may hold the balance of power among the erosive forces) is a loss that is not merely to be deplored; it is a loss that in places is already calamitous in extent and in intensity of local effect....

Although essential watershed requirements can be largely met through range and forest-land management activities, there are certain types of work in aid of watershed improvement that cannot be reached in this manner. This work includes water developments, and the establishment of vegetative cover under circumstances where areas have been so damaged by erosion that special watershed improvement work is necessary to stabilize conditions to a point where vegetation may become reestablished. Other measures include stabilization of upstream channels and stream banks, to help regulate the flow of streams.

Watershed management has far more at stake than site preservation of the watershed. The larger stakes are: Flood protection to the farms, cities, towns, railways and highways of the lower valleys; reduced sedimentation of irrigation reservoirs and farm lands; and increased high quality water production. Examples of downstream dependencies characterizing southwestern drainage basins are given a little further along in the text. In reviewing that brief discussion together with the succeeding discussion on examples of local water problems, students must keep in mind that basic solutions lie in resource management and the restoration of effective watershed cover.

Just as watershed stabilization rests chiefly with resource management so does the responsibility for proper resource management fall on the land manager.

Timber harvesting, logging and brush disposal practices should be adjusted to meet the requirements of local conditions and soil types. Logging roads and skid trails must be properly laid out and after use must be "brushed" in to prevent erosion. Where fire dangers are low and erosion hazards high brush may be lopped and scattered, old gullies plugged and other steps taken to stabilize the area.

Overstocking and overgrazing remains the most serious and widespread form of watershed abuse. Too many stock, poor distribution on the range, too early use and sometimes dual use or the wrong kind of stock are all factors in damaging range watersheds. The grazing

problem is so big that a good part of this section is given over exclusively to it a little further along.

Fire constitutes one of the most serious and direct threats to watershed stability. Fires are often so hot as to virtually denude large areas in a very short time. Where such fires are followed closely by heavy rains the resulting floods and erosion are often extremely hazardous to human life and to downstream property. Fire, by destroying the plant cover, litter and organic matter in the top layer of soild also decreases the infiltration capacity of the soil. During the first summer, soil losses following the Pocket Creek fire in southern Arizona averaged .20 inches or 32 tons per acre from slopes averaging 43%, 90 tons per acre from a 66% slope and 165 tons per acre from 78% slopes.

Naturally the damaging effects of fire differ with localities and soil types but such differences are mainly in degree and as fire risks are further increased by more intensive use of watershed lands additional protection measures will be essential.

As previously pointed out there are times and places where mechanical and structural work is necessary and justified as aids to management. This often takes the form of terracing, water spreading, bank protection or gully stabilization dams such as were extensively used on the Silver City watershed.

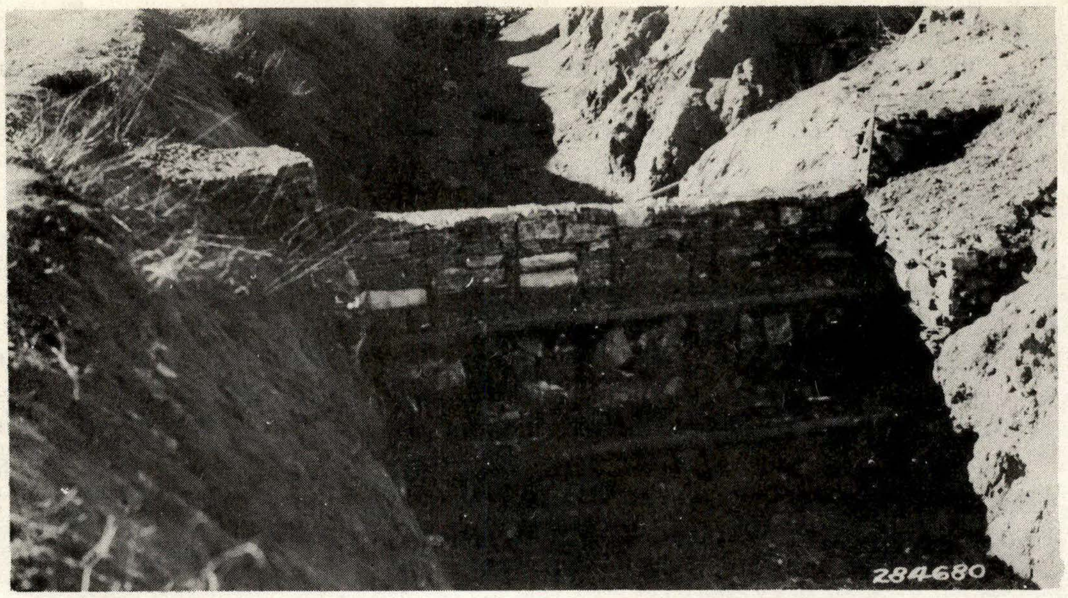


Figure 10 - Channel stabilizing structure Silver City watershed - Gila - 1933.

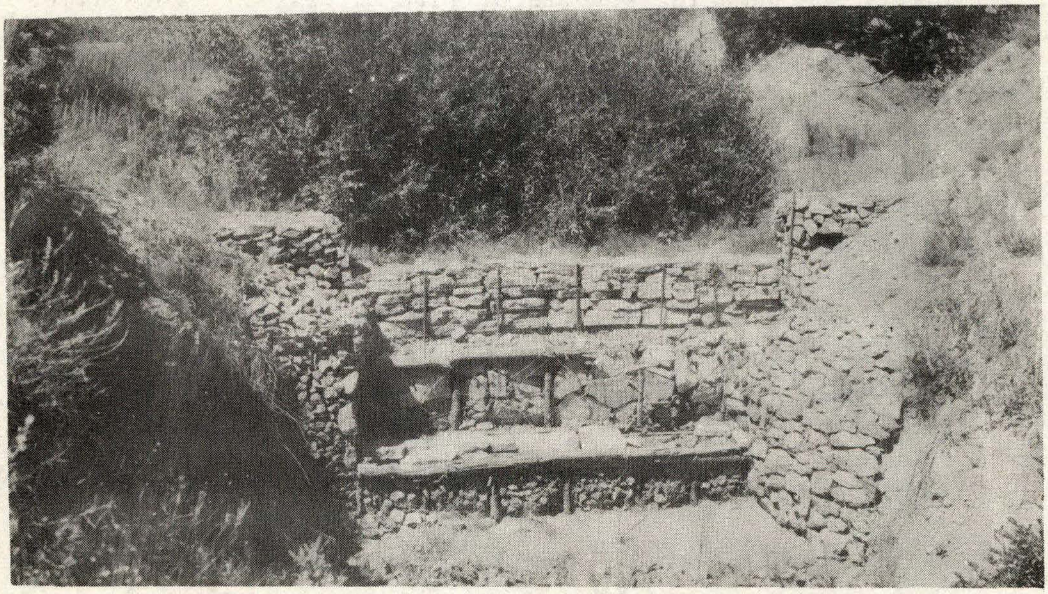


Figure 11 - Same structure - 1944.

Where mechanical control is necessary, the work should satisfy three fundamental objectives: 1) Equalize natural flow, 2) Stabilize the soil within the disturbed watersheds and along eroded channels, thus providing optimum soil conditions for revegetation, and 3) afford protection against floods and spring freshlets before watershed conditions have become stabilized.

Mechanical structures most commonly depended upon in watershed restoration or control work include: 1) Protection fencing, 2) retard or silt detention reservoirs, 3) soil stabilizing structures, 4) protective works, and 5) various forms of terracing.

Watershed treatment to induce percolation as a means of sustaining ground water levels has also been important on some watersheds in the Region.

Examples of Local Water Dependencies

This description deals briefly with the dependencies of streams fed by National Forest watersheds. Water demands for domestic use by cities, towns and rural populations are extremely important and of first consideration. For such use, water quality is of paramount importance although the quantities required amount to comparatively little on an acre foot basis compared to irrigation which constitutes the principal water use in the region.

Irrigation water supplies are obtained from storage reservoirs, direct diversions from perennial streams, and/or pumping from ground water sources. All sources are dependent on the high mountain watersheds for replenishment. Most of the large agricultural developments.

of Region 3 are located in the valley flood plains and are dependent on costly irrigation improvements. Hi-lighting the big developments of the lower basins are the Salt River Valley operations in Arizona. Irrigation and power developments for that district start with Roosevelt Lake and consist of four large reservoirs designed to store nearly 1,800,000 acre feet of water in order to furnish irrigation for about 250,000 acres of fertile Salt River Valley farm lands. Cost of the irrigation-power system, including canals and transmission lines, totals nearly 43 million dollars. Average gross crop values per year for the five years before the War, ending in 1940, amounted to nearly $22,000,000 including livestock products.

Indirect dependencies also include property values and improvement investments in the land and irrigated farms as well as the dependency of some 12 Salt River Valley trade towns including the city of Phoenix with a combined population of approximately 200,000 inhabitants. The prosperity and permanency of the entire valley depends upon the permanency and dependability of the irrigation water supply.

In the case of the San Carlos project on the main Gila, the cost of the Coolidge Dam, including the canal system, amounted to more than $8\frac{1}{2}$ million dollars. This reservoir has a storage capacity of 1,200,000 acre feet, which amounts to a direct construction cost of more than $7.00 per acre foot of storage. About 75,000 acres are irrigated under the project. Within the upper basin are 40,000 acres of irrigated land in addition to that cultivated under the San Carlos project.

In an application prepared some years ago for submission to Congress, a federal grant of $5,000,000 was requested for watershed stabilization purposes on the upper Gila watershed. It was estimated that total dependent property values in the basin at that time amounted to over 50 million dollars.

Major stream courses of New Mexico such as the Pecos, the Gila and the Rio Grande, have all become streams of interstate and international importance.

Some of the downstream values at stake along the Rio Grande are reflected in the Middle Rio Grande Conservancy District figures. Included within the District is much of the City of Albuquerque and large parts of Bernalillo, Los Lunas, Belen and Socorro. Before the war the population of the District was upwards of 65,000, the total value of property between 60 and 75 million dollars. This has materially increased. Further downstream Elephant Butte dam and other large impounding reservoirs were constructed to effect the stabilization of irrigation water supplies and to assure delivery of some 60,000 acre feet of water annually to the Republic of Mexico.

Built at a direct cost of over five million dollars for the dam alone, Elephant Butte lake had an original storage capacity of 2,600,000 acre feet. By 1943, an operating period of approximately 20 years, total district development costs had mounted up to over 20 million dollars, also, by then a half million acre feet of valuable storage

space back of the dam was occupied by mud and silt while great quantities more were choking the channel enroute to the reservoir.

Dependent on Elephant Butte today are not only the treaty water supplies for Mexico but also some 88,000 acres of fertile farming land in New Mexico and 67,000 acres in Texas. In New Mexico alone this represents nearly 6,500 farms. Improved land in the District is said to have sold at from $150 to $350 per acre before the war. Crop values on the New Mexico acreage alone reached nearly 12 million dollars in 1943 and huge property values are represented by the improved farm lands and dependent urban developments in such cities as Las Cruces and El Paso.

Irrigation developments of the Pecos Valley in southeastern New Mexico support an additional 140,000 acres with equally high values represented in rural and urban land values and developments. Although the Roswell artesian area makes up a good part of this acreage its ground water supplies are no less dependent on the high precipitation areas of the forested uplands than if those supplies came down by surface flow instead of via the subterranean channels characteristic of that region.

No picture of the Pecos dependencies would be complete without some reference to the extremely damaging floods that periodically take place through the Roswell-Carlsbad area. For the period 1904 to 1943 such floods were estimated to have caused an average damage of nearly $75,000 annually between Alamogordo Dam and Lake McMillan. This amounts to nearly three million dollars for the period. Such a

situation focuses even greater attention on watershed management and the restoration problem involved in recapturing natural regulation of streamflow.

Silt free water yields are by far the most valuable product and highest use of most national forest watersheds. National Forest watersheds of Region 3 are dedicated to serve three major functions: Water yield, soil stabilization and the regulation of streamflow.

As previously pointed out floods are becoming increasingly frequent and destructive. Sedimentation is also recognized as a constantly increasing menace to improvements and developments in the flood plains. To an undetermined extent these problems still originate on national forest watersheds and it is the first responsibility of watershed management to reduce these problems to a minimum after which more and more attention can be focused on management for increased water yields. Water to be valuable must be usable and with well over a half million acres of irrigated lands in each state the importance of the water crop in Arizona and New Mexico may be roughly estimated by assuming a requirement of three acre feet per acre or three million acre feet per year.

Sample estimates of water yields for drainage units within the national forests run to such figures as these: (Expressed in terms of acre feet of water per section, annually.)

Apache

Drainage Unit	Annual Yield in Acre Feet per Section
North Fork Black River	445
So. Fork Little Colorado	260
Campbell and Dry Blue	220
Aqua Fria Creek	50

Carson	
Rio Hondo	500
Red River	365
Las Tusas	120
Rio Cebolla	75
Gila	
West Fork	190
Sacaton	140
Middle Fork	100
Sapillo Creek	55
Santa Fe	
Pecos River	350
Cow Creek	220
Gallina River	100
Rio Galisteo	85

Unfortunately we have no good estimates on the amount of sediment delivered with this water but we do have erosion surveys which indicate a major erosion problem on national forest watersheds. Widespread studies of the sedimentation problem throughout the national forests is urgently needed.

Examples of Local Water Problems

As stated above, erosion, sedimentation and flood control are major watershed problems of Region 3. Another word or two relating to the scope of this problem and some of the local problems rising out of it seems appropriate. It is estimated that accelerated erosion is present over approximately 80 percent of the area of each state; on nearly half the area it has reached a serious stage. Conditions such as this point clearly to the great need for restoring and maintaining a productive soil and vegetative cover on the watershed. Although much of the silt producing area lies at low elevations our 1939 erosion survey showed over 20% of the gross area of the national forests had reached a very apparent state of active erosion. This is believed to be a conservative classification but illustrates the magnitude of the problem.

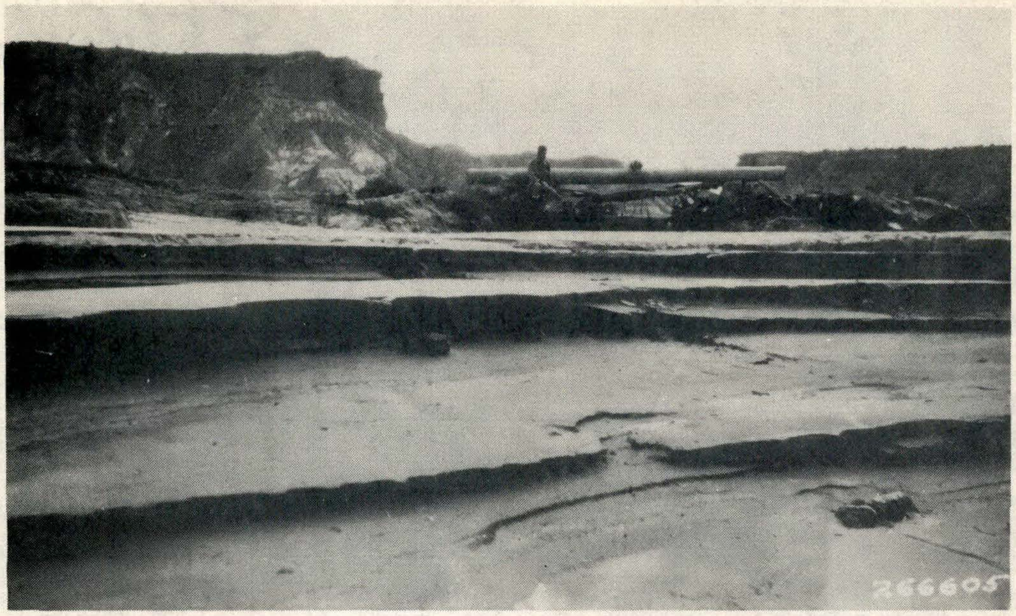


Figure 11a - Silt banked in front of headgate at dam below Cabezon.

Just as silting is a serious problem confronting the Elephant Butte reservoir, which the 1935 silt survey indicates has lost capacity at the rate of nearly 18,000 acre feet per year since its completion, so also is sedimentation the fundamental trouble underlying the problems of the Middle Rio Grande Valley. There, the conservancy district alone has already invested over 11 million dollars in drainage and flood control with the basic problem still unsolved. Irrigated lands in the middle valley are said to have fallen from 125,000 acres in 1880 to 40,000 acres in 1925, largely as a result of water logging due to aggradation of the river channel. Part of this loss was restored in the middle Rio Grande Conservancy District by the drainage project and something over 60,000 acres are now said to be in cultivation.

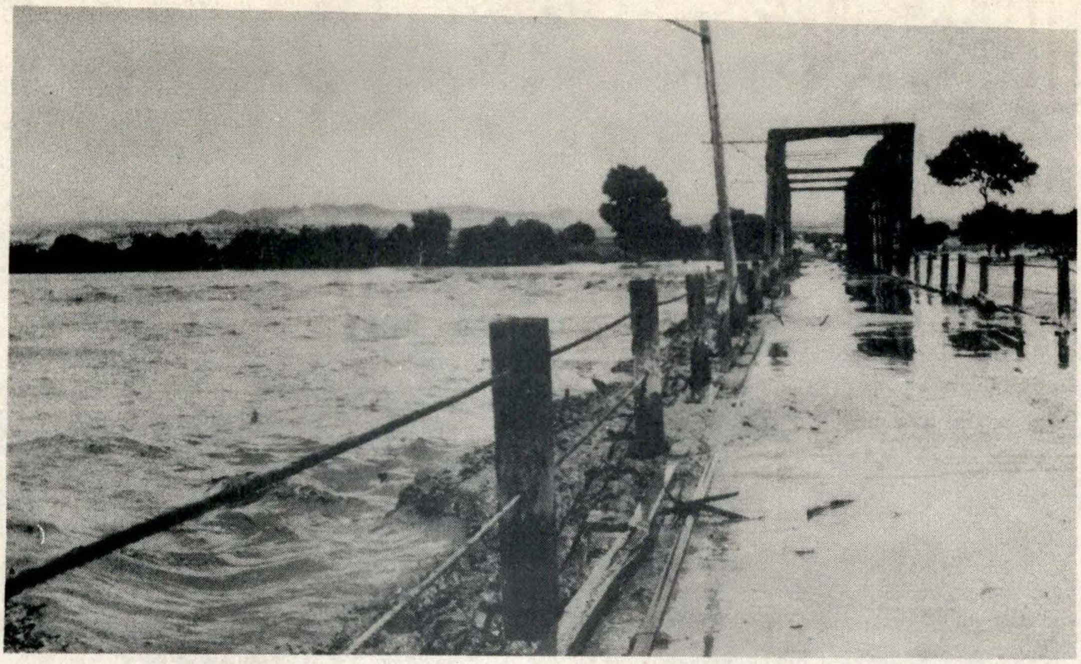


Figure 12 - Silt Choked Rio Grande in Flood - 1935

In the productive Pecos Valley of eastern New Mexico much of the developed agricultural area lies in the river flood plain and floods of recent years have caused serious losses to both urban and rural properties, especially in and around Carlsbad and Roswell. From the data of past floods and the damages sustained, the flood damages to be expected in the future without control or remedial measures have been estimated by the USDA (8) at $58,000 on the main river and $34,000 on the tributaries, annually, exclusive of sedimentation to reservoirs.

Another situation that has become locally important in many of the lower valley farming areas is that of salinity. As a result of accelerated erosion the underlying sub-soils are exposed which add to the progressive concentration of soluble material in the

waters. As a result, the gradual accumulation of salts in the soils upon which these waters are used is cause for serious concern. Restoration of the protective cover will serve to reduce salt concentrations in the runoff.

There are also other considerations in connection with the regulation of streamflow that even go beyond flood control in meeting local needs. In New Mexico alone an estimated 200,000 acres of cropland are dependent upon direct diversion of more or less erratic streamflow. The people dependent on such lands will benefit greatly from the orderly, perennial flow of streams from restored watersheds as against the flash type of water delivery reflected in a feast or a famine water economy with too much water in the spring and little or none later in the summer.

Watershed conditions over the country as a whole have been downwards for the past 30-year period or longer. The 1936 estimates given in the "Western Range" (9) indicate that a vegetative decline had taken place over three-fourths of the western range area with definite improvement occurring on only 16 percent of the range. Those averages are perhaps a reasonably good estimate of the regional situation.

Stocking on the National Forests is known to continue slowly downward towards a more moderate use of watershed ranges. Changes, however, are so gradual and natural recovery so slow as to make it unlikely that the present physical conditions of the upper watersheds will be materially altered for a long time to come and unless this is speeded up we may continue to lose more ground than we gain.

In some instances intermingled land ownership has complicated administration and management—but more important has been the problem of trying to restore seriously depleted watersheds without making sufficient adjustments in use. The whole restoration problem becomes increasingly important when it is realized that erosion and sedimentation are the worst enemies of irrigation, and the production of crops is vitally dependent on irrigation. Siltation damages concern mainly the deposition of silt in irrigation reservoirs. The decrease in reservoir capacity due to silting will ultimately have a serious effect upon the water supply for irrigated areas causing the abandonment of valuable farm lands or costly replacement of the reservoirs where possible. Also in some areas, silt in damaging quantities is being deposited on farm lands and in the irrigation canal systems. The removal of silt from canals entails heavy costs.

Indicators of Conditions and Trends on Range Watersheds

Watershed problems and dependencies are being considered in sequence since damaging or destructive use of forest or range resources can hardly take place in the southwest without having a direct and significant effect on water and soil values of vital interest to the welfare of others.

In many respects the watersheds of Region 3 have two strikes on them at the outset....steep slopes and low forage densities characteristic of semi-arid climates or forested range lands where the herbaceous ground cover struggles under a handicap of shade

and unequal competition for light and moisture. Notable exceptions such as the high parks, meadows and open grassland only serve to prove the rule and accentuate the natural limitations imposed on grazing over most of the national forest range watersheds.

Since such a large share of the watershed problems in Region 3 stem from over-grazing of range lands, particular attention is being given to the range situation.

To the extent that range use does not significantly interfere with plant and soil requirements grazing does not materially alter normal development of the biotic community. Overuse or too early use however is soon reflected in loss of plant vigor, changes in soil temperatures and moisture content and finally in accelerated erosion and distinct changes in plant associations. This results in watershed unbalance and loss of water regulatory influences.

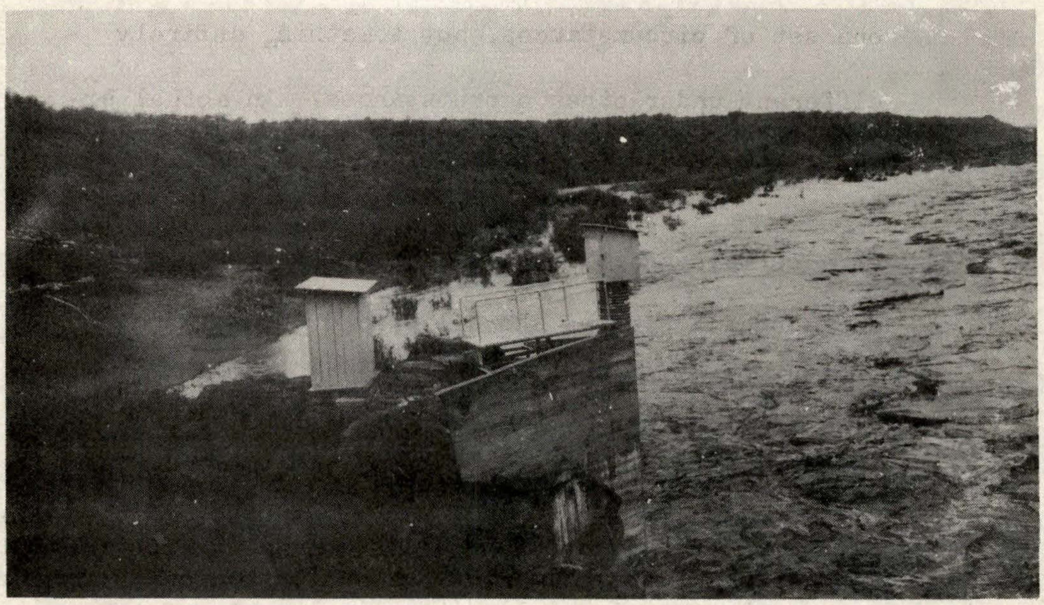


Figure 13 - Salt River in Flood - at Intake Bridge - Tonto N.F.

Changes that take place in the soil, micro-climate and vegetative composition however, do not take place without warning. Disturbance indicators are present almost from the start if one is skilled in reading the signs. Ellison and Croft (7) have covered these factors in detail:

> <u>What is an Indicator?*</u>
>
> An indicator is a sign which suggests to the range manager the character of range condition or of range trend, that is, the state of health of the range. In use an indicator consists of at least two parts. One part is objective--it is some physical thing the observer can see. The other part is subjective--it exists only within the observer and consists of reasoning by which he interprets the significance of the thing he sees. A sign may indicate one thing under one set of circumstances, but something entirely different under other circumstances. An actual example will make this point clear.
>
> On a certain range in late August a very conspicuous and abundant species shows little or no evidence of grazing. This is purely objective--something the

*In this publication the term "indicator" is applied both in an ecological sense and in an extended sense. In the strict ecological sense a plant, a plant species, or plant community, is regarded as being an indicator of environmental factors or processes. In the extended sense the term is applied to all elements of the range-watershed complex, including also such signs as erosion pavement, gullies, or undisturbed soil profile, which may reveal factors or processes that have affected the complex.

observer can see. It is possible, however, to arrive at more than one interpretation: If the species is highly palatable the observer may conclude that the range is lightly grazed; but if the species is relatively unpalatable there is no indication of grazing intensity from this sign alone. To reach a correct interpretation as to the meaning of the sign the observer needs additional evidence. He examines the range closely and finds that there are indeed other species, but these have been so heavily utilized that they are inconspicuous and hard to find. With this supporting evidence the observer concludes that the abundant and conspicuous species is relatively unpalatable, and that the range is heavily utilized because the palatable species are closely grazed.

This example illustrates not only the fact that indicators are subject to widely varying interpretation, depending upon circumstances, but that additional evidence is almost always necessary to interpret correctly the indicator value of an observed sign. Because of these facts indicators cannot be used mechanically in judging range condition, i.e., they cannot be set down in tables with fixed meanings ascribed to them.

Some easily observed signs associated with balanced range are: friable, organic topsoil, well dispersed litter and vegetation protecting much of the ground surface,

and numerous intermingled species, many having high forage value. Unfortunately, microclimate, one of the most necessary of all conditions, cannot be seen with the eye and therefore cannot be used directly as an indicator. But a favorable microclimate is closely associated with visible indicators of satisfactory condition, and may in itself be the reason for their favorable significance.

As a range loses its balance, the surface soil may become hard crusted, and baked; the high degree of dispersal of vegetation and litter may give way to patchiness, permanent bare spots may appear, rills and gullies may develop, and forage value may decline in consequence of undesirable changes in species composition. Here again, although microclimate is not itself an indicator, its nature is suggested by the extent to which vegetation fails to shelter the surface soil and successful reproduction of the stand fails to take place. As the range becomes more and more depleted, the first inconspicuous indicators of unbalance give way to indicators that are more pronounced and unmistakable. Thus the indicators serve not only to suggest lack of balance, but, after balance has been lost, something of the extent of depletion.

Several indicators are usually observable on any range, and each may have a bearing on condition or trend. In some instances the significance attached to a given sign may seem at variance with the significance of other signs--actually when the situation is understood, they will probably not be at variance--so that, to arrive at the soundest conclusion possible, the evidence from all must be considered together.

The extent of the observer's knowledge of the fundamental principles of range ecology will have much to do with the significance he attaches to the indicators, and especially with his ability to reconcile apparent contradictions and arrive at a correct conclusion. This is the reason, in part, for emphasizing fundamental principles in this publication.

Nineteen indicators are listed and discussed in the following pages:[c] 9 are associated with the soil and 10 with vegetation. In the discussion of each indicator an attempt is made to bring out four points in the following order: (1) definition of the indicator, (2) how to recognize it in the field, (3) what it indicates as to range condition, and (4) what it indicates as to range trend. For the sake of brevity it is necessary to treat the indicators as if they occurred separately rather than in the various combinations with other indicators in which

[c]Region 3 illustrations are substituted in quoting.

they naturally occur. This treatment may seem to give each indicator an arbitrary and absolute significance by itself; however, in application no one indicator should be accepted at the full value ascribed to it here without due consideration from evidence of associated indicators, of the extent to which that value actually applies.

Litter

Litter is defined as organic matter that accumulates on the soil surface.

Amount of litter varies greatly with kind of vegetation and therefore the quantity of litter must always be evaluated in terms of the vegetal type in which it accumulates. Under coniferous forest the accumulation of litter may be great, whereas under herbaceous cover the accumulation is usually small. Distribution of litter under coniferous forest is uniform, making a practically complete ground cover. Under herbaceous vegetation, at the other extreme, the thinner litter layer is usually broken. Obviously the litter layer cannot be much more highly dispersed than the vegetation that produces it, and therefore a well-dispersed litter layer accompanies a well-dispersed vegetal cover.

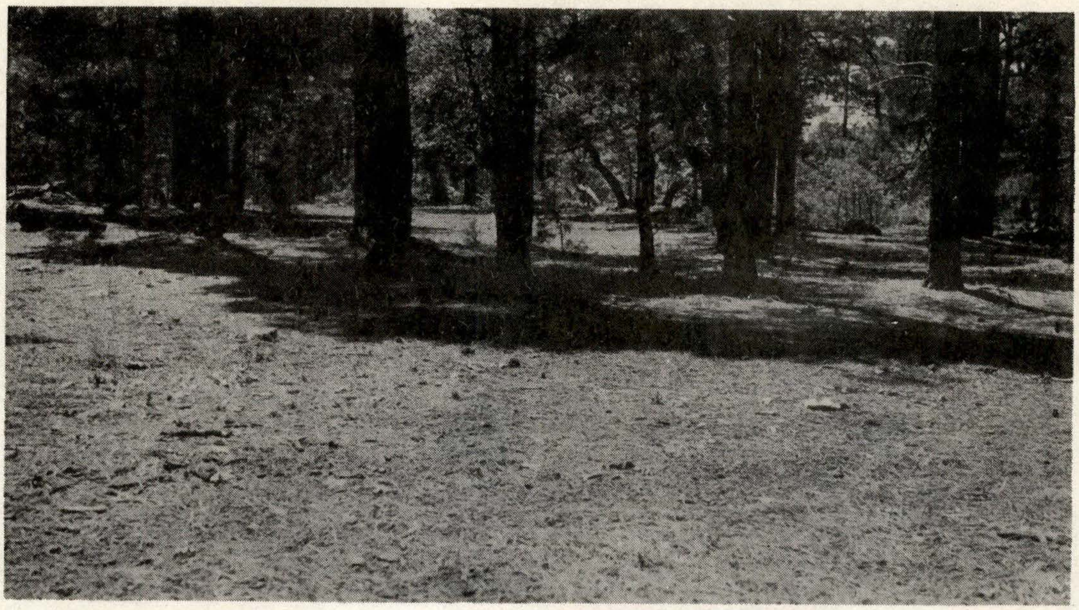


Figure 14 - Litter Under Pine

On herbaceous range the disintegration and decomposition of litter take place rapidly. In early summer the previous season's accumulation can be recognized readily because the plant parts are only partly decomposed, but the litter from two years past is usually so greatly decomposed that only a little dark, disintegrated material can be found.

Condition: A well-dispersed accumulation of litter from the past year's growth, accompanied by well-dispersed traces of older litter, is a sign that considerable herbage has been left after grazing, and it indicates satisfactory range condition. Early in the summer, the virtual

absence or very scanty occurrence of the past year's litter, accompanied by even less older litter, is a sign that little or no herbage is left after grazing and it is an indicator of unsatisfactory condition.

Trend: The value of litter in determining trend on herbaceous range is limited; however, the signs that indicate good or bad condition may suggest corresponding upward or downward trend.

Bare Soil Surface

By bare soil surface is meant a surface either completely bare of vegetation and litter, or with so little vegetation on it that negligible control of the mico-environment results. Bare areas may vary from a few square feet to an acre or more. Even on pristine range some small bare spots occur normally between vegetation but they are well dispersed. Larger bare spots, more conspicuous but also of a temporary nature, often occur as a result of burrowing by animals.

The observer must differentiate between small bare areas where nearby vegetation gives adequate protection to the surface and those so large that little or no protection is given. On the larger bare areas absence of plants not only leaves the soil surface without protection against erosion, but, equally as important, the surface

soil and atmosphere are exposed to excessive heat, wind, and dryness so that the establishment of young plants is made much more difficult. Thus, even though seed supply and soil fertility may be adequate, the unfavorable microclimate of bare areas acts as a limiting factor in normal regeneration of the stand.

Condition: A bare soil surface on mountain range, that is, a well-developed soil not under adequate vegetal control is conclusive evidence that the balance which once existed between climate, topography, vegetation, and soil has been destroyed; and it is therefore an indicator of unsatisfactory range condition.

Trend: As long as bare spots not under vegetal control exist generally over a range, i.e., until the balance is restored, there can be no question but that wind or running water will eat away the soil and that microclimate will continue to handicap plant establishment. Such bare soil surfaces are, therefore, conclusive evidence of downward trend.

Observed Movement of Soil

Observed movement of soil is the visible displacement of soil from its normal position by wind, running water, or the hoofs of animals. This movement may be observed

during heavy rainstorms in the running of muddy water over the surface of the soil, or during windy weather in dust clouds.

As has been explained previously, a small amount of soil displacement takes place on normally balanced mountain range. Throughout the ages of successional change continuous but imperceptibly slow movements of soil have occurred, and no doubt at times movement has been rapid when balance has been temporarily disturbed. However, soil development, extremely slow as it is, has far exceeded soil loss; otherwise, there would not now be soil on mountain lands. But when the surface is disturbed so that widespread soil movement is easily detected by the eye, the normal balance between soil, topography, vegetation, and climate is obviously upset and the slow constructive processes under which soil developed have already been overshadowed by destructive processes which are tearing down the soil many times faster than it can possibly develop.

Condition: Observed soil movement on mountain range is a certain indicator of unsatisfactory range condition. The less violent the rain or wind with which it is associated, the more serious the condition.

Trend: If the movement of soil can actually be observed the conclusion is inevitable that the trend in range condition is downward, and as with condition, the less violent the rain or wind that produces the movement, the more rapid the trend.

Soil Remnants

Soil remnants are relics of surface soil that remain in position after the soil between them has been eroded away. In form they may resemble miniature mesas.

A former continuity of surface from remnant to remnant may be suggested by a similarity in level, or by a repeated appearance of similar parts of the soil profile in each elevated section, alternating with its absence in the depressions.

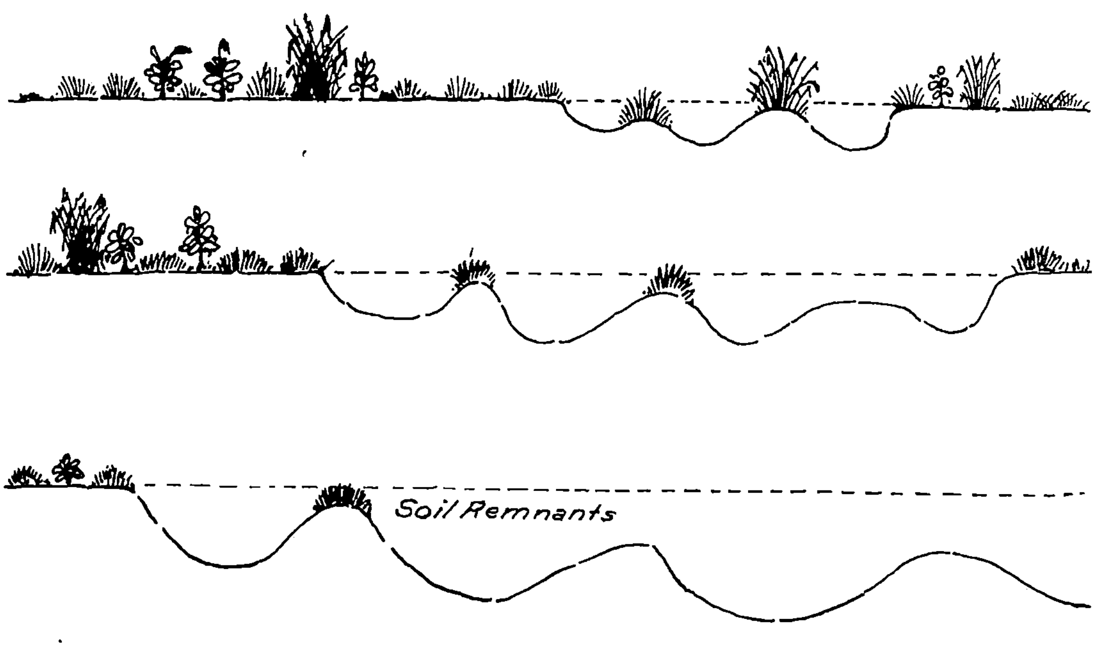


Figure 15 - Illustrating the wasting away of soil surfaces and characteristic soil remnants.

Again, 'islands' of soil above a common level of erosion pavement may suggest the former existence of a continuous mantle.

Conditon: Soil remnants are a sign of partial destruction of a former soil mantle that developed under a balanced relationship between soil, topography, vegetation, and climate. Loss of soil as indicated by soil remnants is therefore an indication of a very unsatisfactory range condition. Absence of soil remnants must not be interpreted to mean absence of accelerated erosion necessarily. Actually, where erosion has been very severe the soil remnants themselves may have been eroded away.

Trend: Soil remnants with plant roots exposed on vertical sides, suggest current soil movement by wind and rain, and as such they indicate downward trend. Remnants with sloping sides, or sides vegetated with mosses and lichens, suggest that a degree of stability has been reached. This condition, alone, however, does not justify the conclusion that trend in range condition is upward, as it may result merely from a temporary cessation of the eroding process. Evidence of an aggressive invasion of vegetation in the bare spaces between soil remnants suggests that a bad condition in the past has been at least partially overcome, and that the trend in condition is upward.

Accelerated Erosion Pavement

Erosion pavement is the name given to the concentration of gravel and rock at the soil surface as a result of blowing or washing away of the finer particles of soil. Beneath the pavement, the soil gives evidence of the presence of organic matter and contains mineral matter ranging from very fine particles to rock the size of that in the pavement.

It is sometimes difficult to differentiate on mountain range between a pavement from accelerated erosion and the erosion pavement usually associated with high geologic normal erosion. The difference is that soil exists beneath accelerated erosion pavement as compared to unaltered or only slightly altered mineral matter beneath rock surfaces produced by normal geologic erosion.

In interpreting accelerated erosion pavement, it must be kept in mind that more pavement is left behind by the erosion of soil with high, as compared with low rock content, and in some cases that all soil fractions may be washed away without leaving a pavement behind. One must be careful, therefore, not to assume that a small amount of accelerated erosion pavement necessarily indicates small soil loss, or that absence of pavement indicates no soil loss.

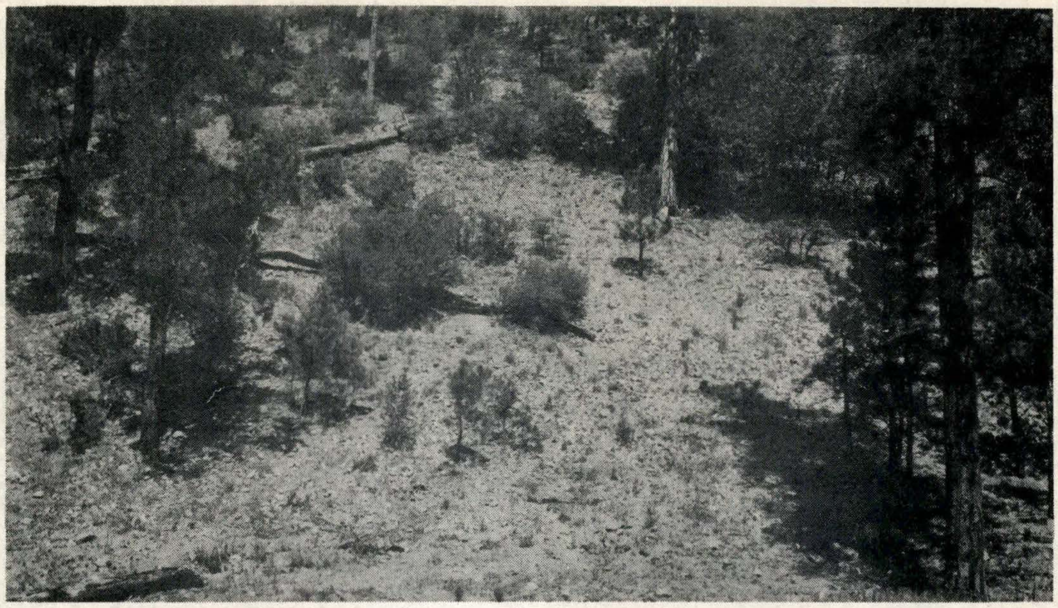


Figure 16 - Erosion Pavement Forming Under Pine - Chloride Allotment - Gila N. F.

Condition: Erosion pavement is an indicator of unsatisfactory range condition because it represents an advanced stage of soil depletion. Moreover as with bare soil surface, the microenvironment associated with such a pavement is very harsh so that natural reestablishment of vegetation is an extremely slow process.

Trend: As a developing pavement provides protection for the soil surface the rate of accelerated erosion is slowed. However, soil loss continues even after pronounced pavement has been developed because frost and

animals bring soil particles to the surface which are easily washed or blown away, so that the trend must still be considered downward. Erosion pavement alone never indicates upward trend. The presence of an old erosion pavement which has subsequently been invaded and overshadlowed by a stand of plants does indicate that the trend has been upward since the conditions prevailed under which the pavement was formed.

Gullies

Gullies are channels cut into the soil by running water, through which water runs only after rains or during the melting of snow.

The term also includes rills which are gullies so small as to be obliterated by trampling of animals, expansion and contraction of the soil as a result of wetting and drying, frost heaving, and wind. The term as used here does not include the main downstream channels or water courses of a drainage system, because these are not in themselves necessarily indicators of range condition. They serve to call attention, however, to the possibility of a depleted condition on the watershed above. The concern here is with gullies that have channeled the soil mantle <u>on the range</u>.

Gullies are caused by rapid overland flow of water which, under conditions of range balance, would normally enter the soil and percolate slowly through it, thereby supplying moisture to soil and water to streams. On a range where overland flow is not normally common, it begins as the infiltration capacity of the soil is reduced by exposure through heavy forage utilization and trampling--that is, as the balance between range components is upset. Once formed in a soil mantle gullies intensify the rapidity of overland flow. This in turn promotes rapid soil erosion and excavation of plant roots. In addition the gullies cause loss of moisture through exposure of a larger soil area to evaporation and accelerated drainage of free water from the soil mantle.

Condition: Gullies indicate extremely unsatisfactory range condition, although like soil remnants and accelerated erosion pavement, they may relate to past rather than to present conditions. However, it must be realized that basically gullies are an <u>effect of unsatisfactory range condition</u> and they should therefore lead the observer to investigate the conditions of the soil surface and vegetal cover which are the <u>cause</u> of the run-off that produces the gully system.

Trend: Inasmuch as each successive flow of water through a gully system increases its efficiency as a collector by deepening and enlarging the system, a gully system tends to be self-perpetuating, and is an indicator of downward trend.

Blowouts

Blowouts are depressions in the surface of the soil caused by wind removal of soil particles.

They may be recognized by residue of particles too large to be blown away resting in windswept and scoured depressions. These depressions usually have no outside drainage. In extreme cases the soil surface is merely a series of such shallow depressions separated by low ridges of vegetation. The depressions may be fairly symmetrical or they may be irregular, a few inches or a few feet across.

Blowouts develop when the soil is exposed to the wind as a result of thinning of the plant cover. Blowouts are not necessarily caused by the occasional gale or hurricane, but by season-long blowing of moderate intensity in combination with repeated soil pulverization by trampling.

Condition: Blowouts are a sign of accelerated soil movement, and they indicate unsatisfactory range condition.

Trend: The character of the surface of a blowout may indicate trend. Thus, if the surface is exposed bare soil, and especially if it is scoured or etched, rapid downward trend is indicated. If the surface is covered with a pavement gravel, downward trend is still indicated but at a slower rate.

Wind Deposits

Wind deposits represent the depositional end of the erosional process that begins with excavation of the soil surface by wind.

Wind deposits are confined almost exclusively within, or to the leeward of, patches of vegetation that catch the moving particles and protect the accumulating material. Such deposits are composed of fine even-textured particles and usually contain no rocks. (However, rodents sometimes bring some rocks to the surface that become incorporated with the blown material.)

Condition: Crowns and stems of plants buried by even-textured material are almost conclusive evidence of rapid deposition by wind at some time and indicate disturbance of the balance in the vicinity. If the deposits are recent, they indicate current unsatisfactory condition. The relative age of deposits may be judged by the degree of discoloration of the surface material by organic matter and also by the degree of decomposition of buried plant parts.

Trend: If deposits are recent, downward trend is indicated. On the other hand, if they show evidence of great age, and there is no reason to think that the source of wind-blown soil has been exhausted, the inference may be made that rate of downward trend has slowed very greatly or that downward trend has stopped completely. It is difficult, if not impossible, to determine upward trend from wind deposits.

Alluvial Deposits

Alluvial deposits consist of soil material which has been dislodged transported over the watershed surface by running water, and laid down again. As used here the term refers to deposits on the surface of the range watershed where condition is to be judged, rather than at the remote mouths of major stream channels. Like badly eroded downstream channels, these large downstream flood deposits are not themselves necessarily indicators of range condition, but they serve to call attention to the possibility of a seriously depleted condition on the watershed. Alluvial deposits may be scattered widely over the surface of a watershed in the form of fans or cones at the end of small gullies, at the end of rills, between clumps of vegetation, and as accumulations back of the crowns of plants or behind litter which has checked water flowing over the surface.

Condition: Alluvial deposits on a range-watershed indicate unsatisfactory condition. Recency of deposition is to be judged by freshness of the deposits. No vegetation, or only annuals, indicate recent deposition; whereas perennial vegetation and especially species that are dominant on the undisturbed range are associated with older deposits.

Trend: As with wind deposits, recent alluvial deposits indicate marked downward trend, whereas deposits on which perennial or woody vegetation has become well established suggest that downward trend has slowed or stopped. As in the case of wind deposits, there is nothing in the appearance of alluvial deposits on which to base upward trend.

Special Composition

By species composition is meant the forage value of the vegetation as a whole to grazing animals. On native mountain range high forage value is usually associated with a mixture of many species, a considerable proportion of which are palatable.

Forage value is to be ascertained by combining careful observations of the palatability and abundance of each species and summing this combination of quality and quantity for all species in the stand. Forage value does not have so direct an application to the primary

objective of range balance as it has to range values secondary in importance to the balance. That is, a stand of relatively low forage value may succeed in preserving the essential balance just as well as one of higher forage value; but the stand of higher forage value is of course the more to be desired. High forage value is the objective in those instances where a balanced condition already exists in the range complex.

Condition: As an indicator, species composition suggests the extent to which the pristine stand may or may not have been depleted as a result of selective grazing. That the plants most eagerly taken are abundant, and that the least palatable species do not tend to predominate, is a sign that the composition of the stand had not been greatly altered by selective grazing. On the other hand, dominance of relatively undesirable species, coupled with scarcity of more palatable species, is a sign that plants of palatable species; handicapped by grazing, have been eliminated from the range, and that plants of undesirable species have been permitted to increase correspondingly.

Seasonal variations in palatability have a bearing on species composition as an indicator. The dominance of species....that are unpalatable during most of the growing season but that become palatable in the fall, after the greater part of their growth and reproduction are

completed, is an indication that components of the stand which are palatable during their period of active growth, have been reduced or eliminated by too heavy grazing. In this instance the dominant species is one that has been able year after year to complete its seasonal cycle of growth and reproduction before being grazed.

Trend: A mixture of desirable and undesirable species will occur either when the stand is improving or declining in forage value. Whichever trend is taking place can only be indicated by a knowledge as to which species are increasing in the stand and which are decreasing. This may be ascertained from a knowledge of their relative ages. (See"Age Classes" - Figure 17.)

Age Classes

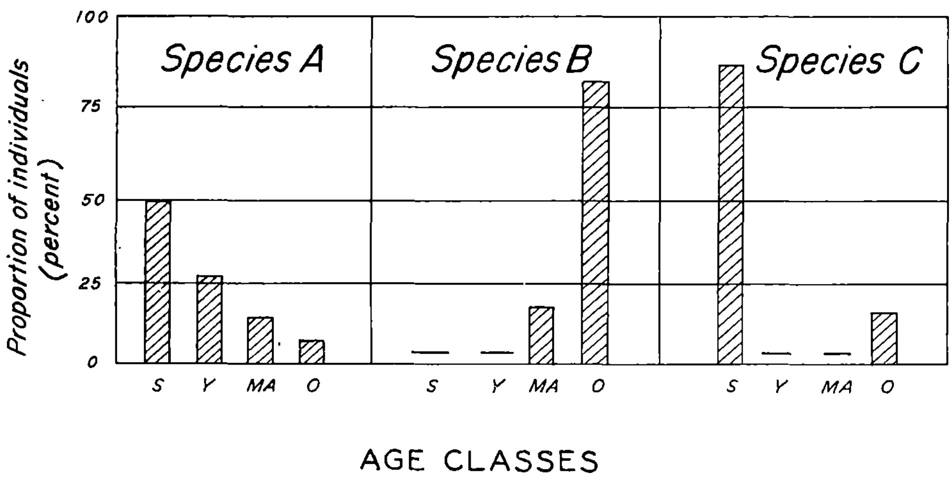
If the individual plants of a given species are grouped even roughly into age classes, the abundance of plants in the varied age groups indicates whether that species is being maintained, or is increasing, or is decreasing, in relation to the other species in the stand. The significance of age-class distribution in range condition and trend depends upon the desirability of the species in question in relation to the others.

While woody plants may be grouped into age classes with relative ease by means of size differences or counts of growth rings, groupings of herbaceous plants

is less easily done. In general, massiveness of root crowns is more or less closely correlated with age in herbaceous plants, and is more reliable for indicating age than volume of foliage. Old grass clumps have a tendency to break up into a number of smaller tufts that may be taken for young plants; often excavation will reveal the former continuity between tufts, however. Similarly, a little digging will often show that small plants which are thought at first sight to be seedlings are really attached to underground parts of old plants. Seedlings can usually be positively identified by the presence of attached seed coats or by their cotyledons.

The accompanying figure illustrates the reasoning in application of age-class indicators. Species A has a fairly large portion of individuals in all age classes, and the indication is therefore that it is maintaining itself successfully. Species B, on the other hand, is represented almost entirely by very old plants, which would suggest that no new plants have become established for several years, and it may be inferred, if the individuals are few, that the species is dying out. Species C is represented by only two age classes--plants that are manifestly old, and seedlings, with few or no plants of intermediate age. Such a distribution is evidence that no successful establishment has occurred for a number

of years. The presence of seedlings, however, may be interpreted in two ways: either the species has begun to reproduce just this year, or it is producing seedlings year after year which, for some reason, never succeed in becoming established. Additional evidence is needed to decide this question.



Diagrammatic representation of age classes of individuals of three species, A, B, and C. S = seedlings, Y = young plants, MA = middle-aged plants, O = old plants.

Figure 17 - Age Classes

Condition: As an indicator age classes pertain more to trend than to condition, since they suggest changes now taking place in the composition of the vegetation.

Trend: In interpreting trend in condition, the essential question is: will the future composition of the stand, as indicated by the tendency for some species to increase and others to decrease, be more desirable or less desirable than its present composition? Thus,

if species B were an undesirable species, the evidence of its passing out of the stand would indicate upward trend in forage value, whereas if it were a desirable species, the evidence would indicate downward trend in forage value.

Roadside Annuals

Roadside annuals are annual weeds common about corrals and along roadsides where soil is periodically disturbed. Some of the most common are: knotweed (*Polygonum aviculare* and *P. douglasii*), goosefoot (*Chenopodium album*), Russian-thistle (*Salsola kali-tenuifolia*), cheatgrass brome (*Bromus tectorum*), and western tansymustard (*Descurainia incisa*). Although they are annuals at low elevations, completing their growth and maturing seed in a single season, a few roadside annuals may become biennials at high elevations. Western tansymustard is one of these.

Condition: Abundance of roadside annuals on a range is a sign of soil disturbance and perhaps of absence of competition from perennials. Roadside annuals are most conspicuous on areas subject to heavy trampling where the numbers of perennial plants have been reduced. In great abundance on the range they indicate unsatisfactory condition. Although abundant annuals may be associated with incipient stages of depletion, their presence as a minor constituent of the vegetation does not necessarily indicate unsatisfactory range condition; having once

become part of the stand they remain on the range indefinitely by colonizing each year the more or less temporary bare spots that occur naturally. An abundance of roadside annuals under perennial vegetation and their absence in nearby bare spaces suggests that the microclimate of the base spaces is too severe for their survival. Their presence does not necessarily indicate a depleted soil, for they thrive on fertile soil as is indicated by their luxuriant growth at corrals and bedgrounds.

Trend: Where roadside annuals are very conspicuous and abundant, one may infer severe soil disturbance. Inasmuch as the annuals give some protection to a recently exposed soil surface they represent limited upward trend. However, if the cause of the disturbance has not been removed, one may anticipate further disturbances likely to result in accelerated soil loss in the future--that is, downward trend.

Invasion of Bare Spaces

Invasion of bare spaces is understood to mean the successful establishment of vegetation on bare soil surfaces. Its recognition depends upon the recognition of plants which are young as compared with the nearby vegetation; and in certain instances upon recognition of the former existence of bare spaces even after the

ground has become partially or completely clothed with vegetation. The recognition of young plants has been discussed under "Age Classes." Recognition of bare spaces is of course no problem while the ground is bare or largely so, but after a vegetal cover becomes established one must be able to infer the prior existence of bare spaces from the evidence of depressions characteristic of eroded surfaces coinciding with marked patchiness in vegetation.

Figure 18 - Invasion by Iris of over-grazed, poorly drained area in Pine type. Campbell Blue - Apache N. F.

Condition: In view of the fact that bare soil indicates an upset balance in the complex, the establishment of vegetal cover points toward restoration of the balance. Perennials low in palatability, or even roadside annuals, are preferable to bare ground. Condition is to be

interpreted first by the degree to which a balance between vegetation, microclimate, and soil is restored as a result of invasion; and second by the desirability of the vegetation that has invaded, as will be discussed more fully below.

Trend: Invasion of bare spaces indicates upward trend. Invasion by palatable species is a more positive indication of upward trend than invasion by unpalatable species, because it indicates that the palatable species present on the range are capable of reproducing under current management. Also, invasion by seed is a more favorable sign than invasion by vegetative means because reproduction by seed suggests the existence of a microclimate at the soil surface favorable for seed germination and establishment. Species like yarrow (*Achillea*) that produce new plants vegetatively are able to colonize certain bare surfaces on which seedlings cannot survive. This is largely due to the fact that the young plant coming up at the end of a rootstock is able to draw on moisture and food from the parent plant until it can exist independently. The seedling, on the other hand, must make its own way almost from the start; and because it is less securely rooted it is more likely to be destroyed by trampling, soil heaving, washing, or blowing.

Vegetation in Gullies

Vegetation in gullies is a special case of invasion of bare spaces in which either the gully bottoms, or the bottoms and sidewalls, become clothed with vegetation.

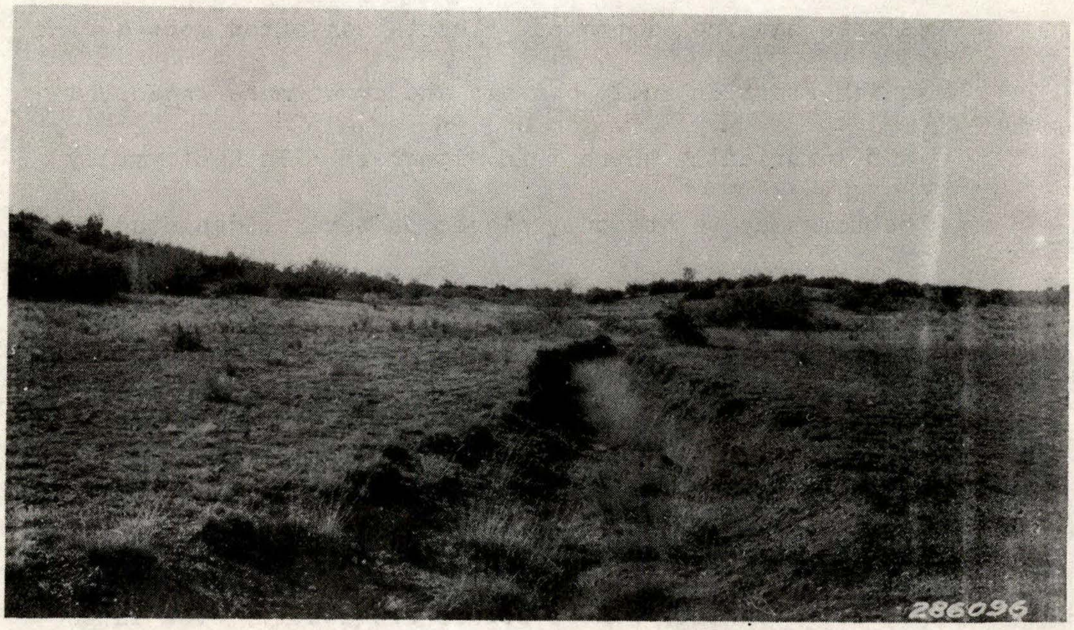


Figure 19 - Natural Vegetative Recovery in Gullies - Verde Valley - Coconino N. F.

Condition: The establishment of vegetation in gully bottoms is widely regarded as proof of change for the better on the range as a whole; this connotation of definite recovery is carried in the common phrase "Healing of gullies." If the area drained by a gully were not properly vegetated, it is reasoned, the runoff from it would destroy the vegetation in the gully and so keep the bottom bare. This is a reasonable

relationship on range where the balance between vegetation, soil, topography, and climate, has been fully recovered; but there are many instances where vegetation is established in gully bottoms even though the drained slopes have not improved. Vegetation often gets a quick start in gully bottoms and grows more rapidly and luxuriantly there than elsewhere. In fact, gully bottoms may be the only places on severe, depleted sites, where certain kinds of vegetation can grow at all. The gully-bottom vegetation may persist for several seasons simply because storms of sufficient intensity to renew gully cutting have not occurred. Moreover, vegetation can persist in some rocky gully bottoms although runoff occurs frequently; even large volumes of water may do no more to the plants flourishing in spaces between the rocks, where undercutting of the banks and deepening of the gully are prevented, than bend them over temporarily. For these reasons, therefore, even though range that has recovered from a state of depletion may be characterized by well-vegetated gullies, the presence of vegetation in gully bottoms is not by itself a reliable indicator of improved range condition. It may be highly misleading if used without a careful appraisal of conditions on the area drained.

Because gully bottoms usually offer especially favorable conditions for plant establishment and growth, the species to be found there may suggest which species on the range are and which are not, disseminating viable seed.

Establishment of vegetation on the sloping sidewalls of gullies is more nearly to be relied upon as an indication of range improvement, especially if the gully shoulders are well rounded and the slope of the banks is gentle. The reason for this is that several years are usually required for the gully walls to reach an angle of repose, and invasion of vegetation on the unstable surface is normally slow. Thus time provides a safety factor in making the assumption of recovery; but in any case, condition as indicated by vegetation in the gully must be checked by close study of the condition of the area drained.

Trend: As with condition, the significance of vegetation in gullies as to trend may be very uncertain. However, the existence of a gully cut into the soil mantle provides a reference point in time for later developments, and if the sidewalls have become well stabilized, the indication is that the trend has been and may still be upward. Similarly, the stabilized profile may furnish a reference point in time for later downward trend.

Patchy Vegetation

Patchiness or lack of patchiness in vegetation is rather difficult to define, since it is the normal thing for plants to be distributed irregularly. Patchiness, as understood here, is the abrupt and repeated alternation between two distinct plant associations. These may be rather dense patches of species resistent to grazing and trampling, alternating with patches made up of ephemeral or short-lived species which provide so thin or temporary a cover as to approximate bare ground.

Basically patchiness is a result of heavy grazing and trampling, the effect of which on the intimately mingled vegetation of balanced range is the elimination of certain species and the exposure of bare areas. These bare areas may be invaded in varying degree, and this has already been discussed. The point here is to call attention to the distribution pattern of the vegetation as an indicator of range condition.

Condition: Insofar as an abrupt and repeated patchiness is a departure from the characteristic mingling of species on balanced range, it indicates unsatisfactory condition. The corresponding indication of satisfactory condition is a stand in which the species are highly dispersed.

Trend: In itself patchiness of vegetation does not indicate whether the trend is upward or downward. The direction of trend is determined by the cause of the patchiness. Thus, if bare or nearly bare openings have been invaded by a certain characteristic group of species, upward trend is suggested.

Accessibility of Palatable Species

Accessibility is the extent to which plants can be reached by grazing animals.

Difference in accessibility may be provided by barriers to movement such as cliffs and lava rock, or by mechanical hindrances to grazing such as stiff and thorny crowns of shrubs. Comparisons of the vegetation on accessible and inaccessible spots which occur close together provide a basis for estimating the change in vegetal composition on the range as a result of grazing. Reasonable comparability of the accessible and inaccessible spots must first be established.

Condition: The more or less uniform distribution of palatable species on accessible and inaccessible spots is a sign that the composition of the vegetation has not been materially altered by grazing, and satisfactory range condition is therefore indicated. On the other hand, that the palatable species tend to be confined to inaccessible spots suggests that grazing has eliminated

them from the accessible range and that condition is unsatisfactory.

Trend: The fact that certain desirable species occur only in places inaccessible to grazing animals may provide indirect evidence of trend. If numbers of young plants of these species, well beyond the seedling stage, occur on the grazed range, a lessening of grazing pressure is suggested and, to this extent, a turn for the better. However, if few or no plants of the species under consideration are present on the grazed range the indication is that trend is downward.

Relics

Relics are remnants of former vegetation and provide a means of visualizing its character after most of it has undergone modification. A relic may be a remnant of a plant community (c9mmunity relic) or it may be a single persistent species (plant or species relic).

A patch of timber in the midst of a burn is an example of a community relic--a relic of a community destroyed by fire. The stumps of a heavily grazed species of shrub provide an example of a species relic. They indicate the existence of the shrub in a former vegetal association now largely destroyed by overgrazing.

Insofar as grazing is concerned, community relics are to be found in places where grazing animals have never

or seldom been because of physical barriers or distance from water. Species relics resulting from overgrazing, on the other hand, are to be found on grazed range. They may be recognized by one or more of the following characteristics: They belong to species that are not common and indeed may be exceedingly rare on the grazed range, but that may be abundant in protected areas; they tend to be almost wholly old plants low in vigor, and many of them are the remains of dead plants; they give little or no evidence, from survival of young plants, of reproducing successfully; and they are grazed excessively close.

Relics are a natural consequence of normal plant succession and some have no direct relation to grazing. It is necessary, therefore, to ascertain the process by which a given species has become a relic in order to know its significance as an indicator.

Condition: The significance of relics in relation to grazing depends upon their palatability as compared with that of the other species in the stand. If the relic species is highly palatable an unsatisfactory condition resulting from excessive grazing is implied. In the picture of shrubby cinquefoil relics unsatisfactory condition is indicated on two counts; one by the destruction of this palatable plant--which is the point of this discussion--and the other, which is the

more important indicator, by the unbalanced condition resulting from the exposure of much bare soil.

Trend: The existence of relics of palatable species, particularly if supported by evidence that young plants of that species are not becoming established, suggests downward trend in forage value. On the other hand, if together with the relics there exists a population of young plants that are well established, upward trend from a more depleted condition is suggested. Another indicator of upward trend would be relics of an unpalatable species in a stand of relatively palatable species. The relics in this case would of course not bear the marks of heavy grazing in the past as they would if they were relics of palatable species.

Hedged Shrubs

Shrubs or low trees that exhibit more or less smooth crowns which are densely twiggy at the margins, like clipped ornamental hedge fences, are said to be hedged.

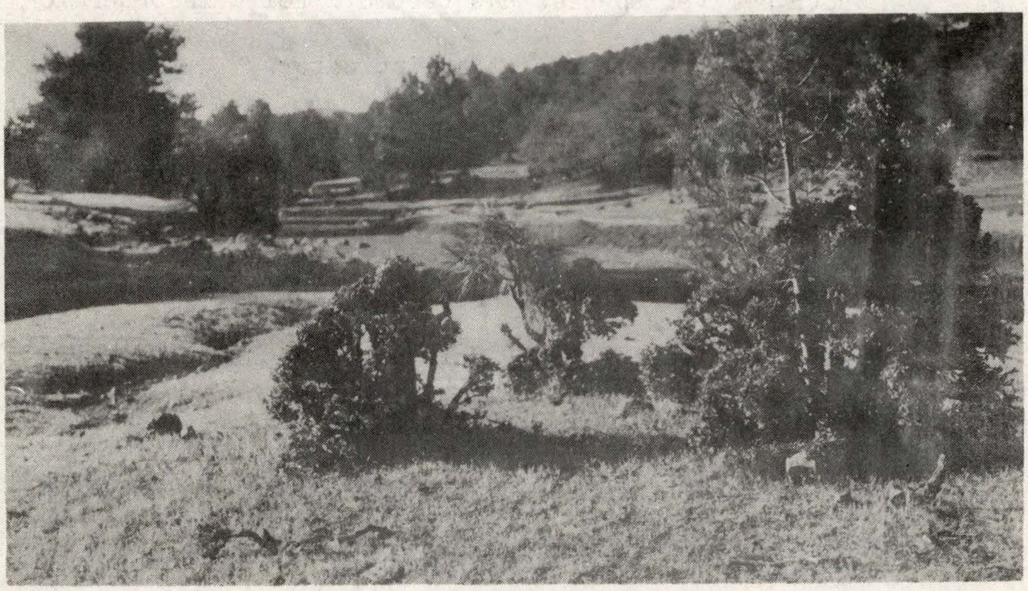


Figure 20 - Hedging of Mt. Mahogany - Gila N. F.

Examination of such shrubs will show the condition to be the result of repeated death of the terminal buds or cutting back, year after year, of the annual shoot growth. The former may be the result of natural causes such as recurrent frosts, or recurrent attacks of parasites, whereas the latter is a result of browsing. If the hedging occurs only as high as animals can reach, the supposition that it is caused by browsing is confirmed.

Condition: Hedging is an indicator of heavy utilization, not necessarily of the current year, but of past years. Absence of hedging, if the species is positively known to be highly palatable, is a sign that use has not been heavy enough to inhibit normal growth, and to this extent absence of hedging may be considered an indicator of satisfactory condition. This interpretation should be guided by the same knowledge of relative palatability as applies to "Current Utilization" and to "Relics." Like these indicators, it does not directly suggest range conditions with respect to the existence of balance or lack of balance in the complex, but simply with respect to forage value.

Trend: As an indicator of trend, hedging suggests diminishing forage value. If hedging is accompanied by much dead wood in the crowns, suggesting low vigor, or

by dead plants, the indication is that over-browsing of the species has continued for a long time. An indicator of upward trend in forage value is provided by the appearance of several years' normal growth above old hedged surfaces.

Current Utilization

The extent to which current growth is grazed constitutes the utilization of that species for the season, and is designated as "current utilization" to distinguish it from the utilization of past years.

Figure 21 - Conspicuous Over-utilization Outside of Forest Boundary Protected Area - Mangus Valley - Gila N.F. (Fenced 1935 - Picture 1937)

Obviously the degree of utilization cannot be ascertained directly, rather, it is inferred by subtracting the amount left from estimated total production. A statement of

utilization is therefore basically dependent upon the observer's estimate of the total amount of each kind of forage produced. This estimate may be formed in part by a comparison at the end of the grazing season with bits of range protected in hurdle plots, but for the most part it can be built up only by intimate acquaintance with the vegetal composition of the range and grazing preferences of the animals at the beginning and middle, as well as the end, of the grazing season. On many ranges observations made solely at the end of the season are necessarily limited to the less palatable species, because the more palatable species have been grazed off so closely that they cannot easily be found. This situation has been noted again and again, until it would seem to be not so much the exception as the rule.

This fact does not seem to be widely realized, which suggests that many range managers assume that they know, but do not actually know from their own observation, what the relative palatabilities of the various species are. It seems obvious that the utilization cannot be appraised in its true significance unless the relative palatabilities of all species in the stand are known, if only roughly. So far as arriving at an indication of range condition or trend is concerned, it is therefore less immediately important to know the precise percentage utilization of a few species than it is to

be able to list all the species in the stand in the approximate order of the use they receive.

Current utilization must be considered also from another point of view--that of loss of cover, and with it loss of protection to the soil against heating and drying by the sun, blowing by the wind, and washing by the rain. Thus, regardless of whether plants are killed outright by being cropped too closely, or whether undesirable changes in species composition take place, heavy utilization carries threat of accelerated erosion and failure in reproduction. Current utilization must therefore be appraised not only in the light of its direct effects upon the plants, but in the light of its effects upon the microclimate and soil.

Condition: Intensity of current utilization is a direct reflection of intensity of stocking, but interpretation must be guided by a knowledge of the habits of the grazing animals, especially as their habits are modified by seasonal changes in palatability, and by topography. Although heavy utilization is an indicator of unsatisfactory range condition, current utilization is, in general, not so much an indicator of present condition as it is an indicator of what future condition is likely to be, and so it is more an indicator of trend.

Trend: Heavy current utilization of a certain species, as compared with lesser use of others, is a sign that the species in question is being handicapped. Continued heavy use may result either in preventing the reproduction of that species or in the outright death of established plants, and is therefore an indicator of downward trend in forage value. If the species is low in palatability, or if the most unpalatable parts, (e.g., coarse stems) are grazed, the steepness of trend is all the more pronounced. If the most desirable species are moderately or lightly grazed, however, and have the opportunity to flower and scatter seed, there is some reason to expect increase of those species. One necessity--a seed source--at least has been provided, and upward trend will depend in part upon the success with which new plants become established.

Heavy utilization generally may be considered an indicator of downward trend if it results in exposing much bare soil so that in clear weather the soil surface heats and dries unduly, and in wet weather soil washing and erosion take place.

The necessary precaution in the use of indicators, that all available indicators be used and carefully weighed against one another, is especially applicable

to the use of current utilization. This is so because the common tendency is to use current utilization alone as the criterion of range trend, ignoring all other indicators. While current utilization has its place as an indicator of trend, it must be emphasized that current utilization simply reflects the grazing use <u>of the current year</u>, while range trend as a whole is ordinarily the accumulated result of diverse forces operating over many years.

V - Field Methods

Field tests in judging conditions, stability and trends of watershed soils are suggested through the use of the "Soil Type Rating Guides and Score Card." This has been purposely worked up along lines previously developed by the "Southwestern" in judging range conditions so that both cards may be used without confusion.

Field Tests

In field tests it should be remembered that the observer is out to determine what is taking place on the watershed and what his observations mean with respect to improvement or deterioration of watersheds. Perhaps the first thing to observe is the condition and current use of forage. This subject has been considered and is also too well covered in range management courses to require further consideration here. At the risk of some duplication however certain general observations with regard to the condition and use of the vegetative cover seem in order in the discussion of field observations and tests.

To begin with a good knowledge of the identity, characteristics and palatability of range plants is essential. At every opportunity observers should compare notes as to the various species making up the composition of that locality and consider what inferences may be drawn as to current and former grazing use from an analysis of the volume growth and use, appearance and plant association represented. Current over-use may be accepted as a forerunner of change unless immediate remedial action is taken. It is usually one of the first

indicators of deterioration. Species change is not always too sensitive an indicator of what is taking place and may be the tardy effect of a situation that has been in effect for some time. As discussed in the preceding chapter, heavy use of individual species indicates that the species in question are being subjected to distinct growth handicaps. The wider the range of species over-used the greater the total handicap. Continued over-use results in loss of vigor, reduced density and enlarged bare areas. These effects can readily be observed in the field, the bare areas often still retaining a soil cover not greatly different from the non-depleted areas surrounding it. As these bare areas enlarge they are frequently invaded by annuals, lower scale perennials or tree reproduction such as juniper. Broken cover and reduced competition from grasses probably being largely responsible for the successful establishment of seedlings now taking place in many of our better grama types are "going to juniper." In some instances these broken areas or patches are invaded by annuals or other perennial grasses, less palatable or more hardy than the favored species being displaced.

Figure 22 - Weed Invasion and Occupation of Bare Areas. Note erosion activity indicated by soil deposit above log terrace. - Lincoln National Forest.

"Sod Muhley" may occupy such areas in a broken gramma stand, three-awn may invade a curley mesquite type while burro-grass often crowds into such areas on tobosa grass types, the long and short "patches" giving a mangy appearance to the range. Under certain soil and moisture conditions this typical "patchiness" may thus be just as much an indicator of serious vegetative depletion as the bare areas themselves. Other characteristics of over-grazing are of course over-use of the better forage species and almost any use of the less valuable ones, conspicuously hedged or closely used browse.

plants and shrubs, lack of reproduction of favored species, the occurrence of coarse weeds and grasses of low palatability invading forage stands of high palatability. This serves as a brief summary of the outstanding vegetative factors that are usually analyzed in leading up to a consideration of the more advanced indicators usually associated with significant soil depletion and water erosion. Wind erosion is of scant importance on national forest ranges. What to look for:

Soil Signs of a Deteriorating Watershed

Soil Creep: In thinning vegetation, particularly on slopes, insiduous soil movement begins to take place. You will notice a tendency for soil to pile up somewhat against the upslope crown of grass clumps while moving away from the downslope side where it piles up against the crown of the clump below. This "up-slope" collared appearance indicates the beginning of soil creep and may frequently be noted on the steeper bunch grass slopes.

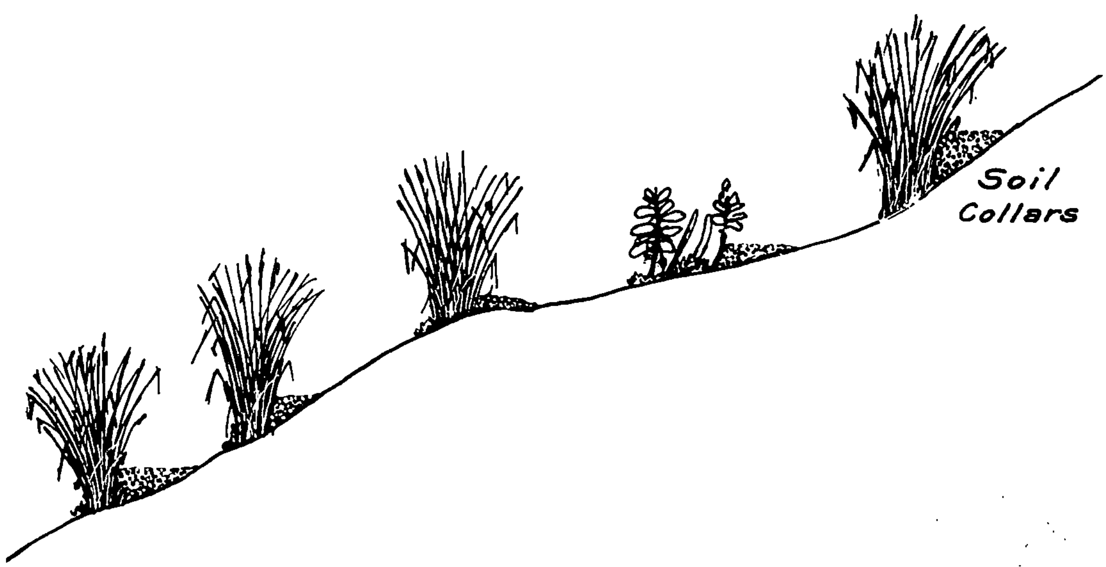


Fig. 23 - Soil creep illustrated by soil collars above grass clumps.

Disappearance of Litter: Bare ground resulting from the disappearance of litter, particularly in shrub or tree types usually indicates increase in surface runoff that has washed away the litter. Frequently this litter may be piled up in nearby washes lodged against rock, roots or sand bars. Its loss is a distinct handicap to surface soil protection.

Early Sheet Erosion: May first become evident as a result of exposure of plant roots, minor soil accumulations on the upper side of down logs and limbs or grass clumps. Carefully compare any nearby protected soil spots with the overused areas and it may be found that in the latter areas much of the finer soil materials have been carried away, with the remaining coarser material beginning to resemble light gravel and to assume the appearance of erosion pavement in its early stages. Runoff water is murky and small soil depositions are left where it spreads out on flats.

Rill Erosion: Rill or incipient gully erosion in its early stages is most noticeable where runoff has converged to follow natural surface depressions or drainage ways. Rill erosion or incipient channel cutting is usually an indication of increased water accumulations in drainage ways that formerly accommodated the normal runoff.

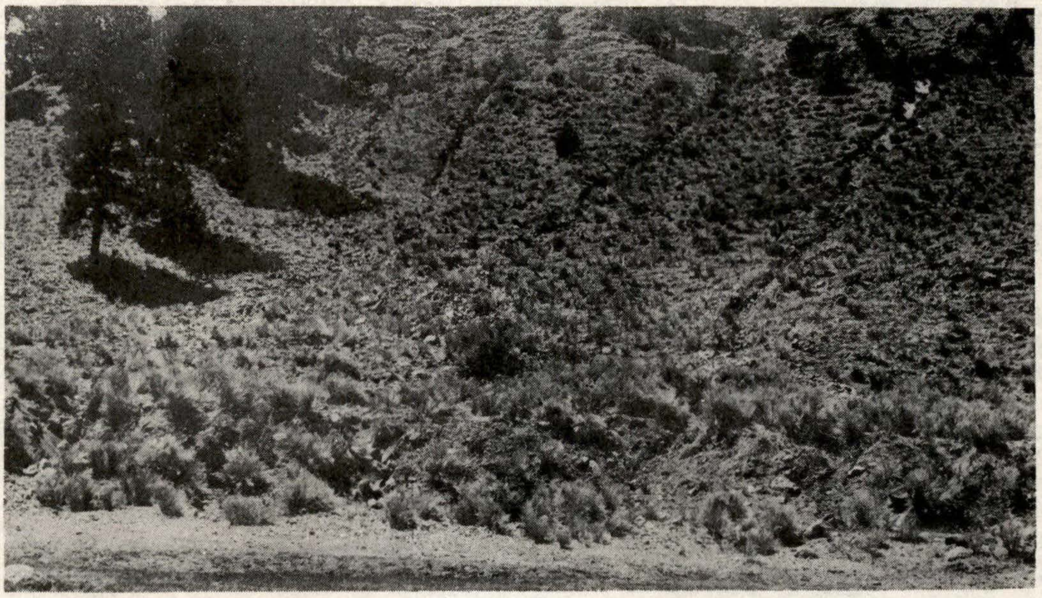


Figure 24 - Rill Erosion - Canyon Largo - Apache N. F.

Rill erosion has a tendency to further concentrate runoff due to converging channels and rapidly grows into gully erosion if remedial stops are not prompt and effective. In observing rill erosion note particularly where it starts. Often it results from something damming up excessive surface runoff into small cutting heads then giving way. Note the angles of the small channels as to whether they are sharp with active cutting continuing or rounded indicating that they are no longer serving as active drainage ways. If the latter is true try to determine whether relief has come as a result of drainage diversion or general range improvement.

Advanced Sheet Erosion: Is characterized by critical loss of productive top soils. This is usually evidenced by light soil colors due to loss of the darker material through floating away of the top soils containing most of the organic matter. Remaining soils are apt to be sandy, gritty and mineral-like in character or hard and sun-baked due to the action of the sun and water on soils no longer capable of taking in and holding water which is a primary function of the organic matter in soils. Note the structure of such soils, and if protected areas are available in the vicinity compare handful samples as to color, texture, structure and recognizable organic matter such as decaying wood, leaves and other plant material.

Next note the way the roots are exposed and the crowns of remaining vegetation perched high above the surface of the ground or hummocked, particularly in instances of loose, sandy soils being shifted by winds. Coarse erosion pavement is apt to be conspicuous or sub-soils are often plainly exposed. Where parent formations were close to the surface the bed rock is often bared. Soils bearing very little rock or gravel naturally erode away without leaving much of an erosion pavement and this should be discounted in appraising conditions. Runoff is usually muddy.

Advanced Gully Erosion: Is characterized by deepening or widening of old washes or abnormal trench cutting of sharp new drainage channels through the watershed. Such gully cutting is often very destructive, progressing through undisturbed soils by headward

cutting - deepening by channel wash and widening by meander of the flow and undercutting of the banks, the sloughed material being periodically carried on down by flood flows.

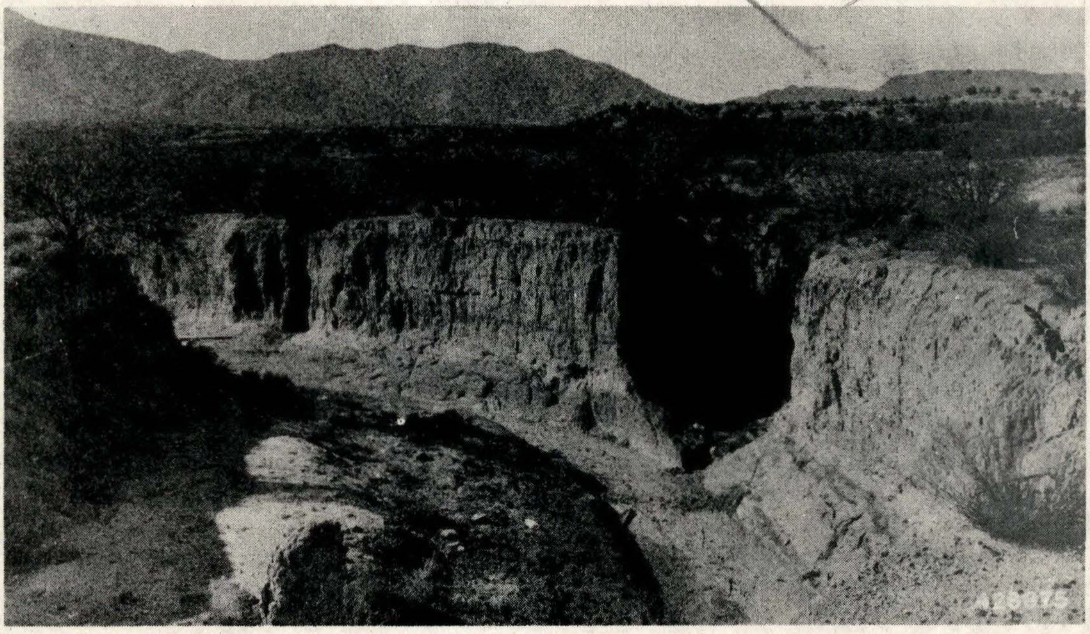


Fig. 25 - Active Gully Cutting - Verde Valley - Prescott N. F.

Active gullying is characterized by steep, perpendicular or overhanging banks. Gullies and gully extension can readily be observed in the field and the apparent cause of gully determined. The term "apparent cause" is used advisedly since there is a natural tendency to blame gully cutting onto stock trails, abandoned roads, unsatisfactory road drainage, heavy storms or some other more or less commonplace factor that may appear to be the basic trouble whereas the true overbalancing factor that has resulted in destructive cutting is the increased rate of runoff building up drainage heads

to soil cutting proportions. This has generally come about as a result of disturbances in the form of forage depletion on the slopes. Gully systems are prone to self-perpetuation unless drastic remedial measures are taken which must as a rule include stocking adjustments and sometimes requires supplemental structural control. Gullies, particularly those cutting back through well sodded range furnish an excellent opportunity to examine soil stratification and to make visual comparisons of the several soil strata exposed in the gully banks. This is an excellent opportunity to observe differences in color, texture, and structure of soils.

The earmarks of improving ranges are also exposed on the surface and may be satisfactorily interpreted by those who will carefully examine and weigh the evidence:

Soil Signs of an Improving Watershed

Reproduction: Perhaps the most outstanding vegetative sign of an imporving watershed range is an abundance of small plants or reproduction of the more favored, higher-level, perennial forage species. Successful establishment of mt. mahogany seedlings, curley mesquite runners or other grasses from natural seeding is usually an indication that conditions for establishment have been favorable for several successive years. Therefore, such establishment usually carries with it some assurance of improved conditions and increased soil stability.

Light utilization of favored grasses or browse is also a good sign but must be fully considered in the light of current volume production, grazing conditions and seasonal grazing use. The establishment of reproduction through natural vegetative spread plus light use of favored species is definitely a favorable trend. Since most of the better known earmarks of improving vegetative conditions are discussed in considerable detail elsewhere further consideration here will be given over to those indicators relating more directly to soil conditions.

Sheet Erosion: In addition to a vegetative analysis of the area the examiner should observe the amount and condition of litter on bare ground surfaces where serious herbaceous depletion has occurred. Close to coniferous forest trees the deposition of needles and branch material should be considerable. In other types, proportionately less may be expected. A well dispersed litter should accompany a well dispersed cover.

Examine the depth and composition of litter. Does it consist largely of the current year material or is there evidence of rotting material for several years back? If several ages of litter are discernible it usually indicates some reduction in surface runoff and consequent improvement in soil stability.

Fig. 26 - Vegetative litter left from annuals on denuded range. If enough of the annual growth is left each year soil fertility will gradually build back. This old annual growth is the only hope left for soil restoration.

Litter also takes the form of small vegetative windrows or terraces left by surface runoff as it lodges against small pebbles or stones. These small windrows of decaying vegetation gradually build up depleted soils and shield the soil surface from the direct force of sun and storm.

This gradual masking of bare areas with litter is a distinctly favorable trend.

Is the surface soil, often characterized by coarse erosion pavement or conspicuous soil "islands" or remnants of topsoils, beginning to accumulate an intermixture of vegetative particles that can be distinguished in a close examination. Where it occurs this is usually an encouraging sign of an upward trend since such material is readily floated away by surface runoff.

Gully Erosion: May often be active long after corrective measures have been taken. As a general rule signs of reduced runoff are reflected in stabilized channel conditions that result in rounded banks with generally less precipitous cross sections. Slopes gradually assume an angle of repose - vegetation will be seen establishing itself in the gully bottoms and on the banks. At the head, the caving banks will have piled up almost to the lip leaving a scant over-fall. The vegetation, slipping down with the caving lip often continues to grow and stabilize the soil mound in the gully head.

The two outstanding characteristics of upward trend in natural gully control are subdued and rounded gully slopes and the re-establishment of the natural vegetation in the bottom and on the sloping banks.

Inspection

Judging a range watershed: Is no simple matter and must be carefully and systematically done if it is to faithfully reflect watershed conditions. In this connection Ellison and Croft (7) suggest that careful sampling:

> ....is of fundamental importance in making observations on the range. It does not matter how the observations are made, whether extensively as one rides along or intensively on detailed study plots; the principle is the same. The entire forest or the entire allotment cannot be observed in detail; one can make observations only on what he can see in traveling over a portion of it, and from that portion draw conclusions as to the rest. This portion he sees is a 'sample,' and his effort should be to get a sample that is representative of the whole.
>
> All too often the assumption is made that a sample is representative when in fact it is not. This is more often true than is commonly realized, for people frequently speak loosely of a 'representative cross section' when they have no basis other than wishful thinking for believing in its representativeness. A frequent reason for lack of representativeness is that the character of the sample is influenced by some sort of bias or systematic error which is not reckoned with. Bias is the tendency to favor certain parts of the material being

sampled and neglect other parts; often it is entirely unconscious.----

An example of biased sampling is provided by the preponderance of study plots and enclosures on level or essentially level land--whereas the greatest part of the range itself, and much of the most critical range, is not level but sloping. Study plots and enclosures thus located do not actually sample the range; they merely sample that part of the range which is level. The danger in this is that the trends on level land are often quite different from the trends on nearby slopes, and, in consequence, results from such study plots may actually conceal rather than reveal trends on the range as a whole.

There is plenty of chance for bias in range inspection, for it is natural to take the easiest route--up the valley bottom or ridge rather than across them and across the slopes, for example; but the easiest route is not necessarily the route that will give the best sample. The best sample is the one that includes the full variety of conditions in representative proportions. The common practice of selecting a single area, or a few areas which are considered to be "representative" in place of a sample that within practicable limits includes <u>all</u> conditions is particularly liable to bias.

Experience has shown repeatedly that such selection may result in disastrous error.

Inspection at only one time, like inspection in only one place, may give misleading results because conditions--stages of plant development, degree of utilization--vary greatly over the season.

Getting a representative sample of conditions on an allotment may be summed up in the saying that good range management depends as much on proper distribution of the range manager as on a proper distribution of the livestock.

In planning an inspection of the range it is necessary at the outset to appraise the elements involved, so as to know the conditions to be sampled and so that the various parts of the allotment may be rated with respect to their importance. The principal elements to be considered are character of vegetation, utilization by grazing animals, stage of development of vegetation, local climate, character of soil, and steepness of slope. These elements are combined into an estimate of relative importance, giving priority to those areas on which range condition is believed to be most critical. Necessarily this preliminary appraisal, from memory and at a distance, must be rough; the inspection itself should supply the information for a more exact appraisal of

range condition and thus for getting a more truly representative cross section the next time.

Although it may be found on the ground that the preconceived plan cannot be followed exactly, so that changes in route of travel and time for the job must be made, it is still essential in making changes to be guided by the principles of representative sampling and to strive at all times to lessen the likelihood of bias.

Observing and Recording Facts

The value of conclusions reached for any particular site examined, and accordingly for the entire area being examined, will depend on the level of intensity at which observations are made, the soundness of the reasoning used in reaching conclusions, and the thoroughness and accuracy with which the observed facts are recorded.

There are two levels of observation in range inspection: One extensive and the other intensive. From observations at the extensive level the inspector can get an idea of only general over-all features of the range, i.e., the extent and character of vegetal types, topographic features, distribution of livestock, and the more obvious range conditions such as gullies, bare soil, or erosion pavement areas. The inspector uses this level of observation

in selecting the sites on which intensive observations are to be made and extensive observation is therefore helpful in getting a representative sample of the area being inspected.

Intensive observations on small areas are necessary to secure the detailed facts from which the only valid conclusions of range condition can be made. If improvement or depletion is taking place, the inspector ought to recognize them in their incipient stages. The incipient stages, however, are never conspicuous; the signs that mark them are always small and often are visible for only brief periods. To observe and understand the facts close to the ground requires great and constant effort at the intensive level. These facts cannot be observed from the seat of a car, or from the back of a horse, or even from walking over the range; the observer's eyes and fingers must be closer to the ground than that--his most reliable observations will be made on his hands and knees.

Keeping the foregoing sampling procedure in mind the accompanying "Soil Type Rating Guides" are prepared for field use in recording intensive soil and site observations. Use of these guides in connection with the use of the range judging guides developed by Mr. Parker of the Southwestern Forest and Range Experiment Station may often be desirable. Together the guides should provide land managers a useful, safe and uniform method for judging satisfactory land management from a range and watershed standpoint.

SOIL TYPE RATING GUIDES

(See accompanying rating card--page 139)

An effort has purposely been made to follow the Southwestern's range judging scheme so that the rating sheets may be used together or alternately without confusion. Overlapping factors such as "slope" may properly be considered on both sheets as affecting range use and soils from somewhat different angles.

SOIL DEPTH

Self-explanatory on the rating card.

SLOPE

Self-explanatory on the rating card.

INFILTRATION CAPACITY

(Soil structure, or the extent to which individual grains cling together into clusters and which is roughly related to the humus content, is a determining factor of infiltration rates because of the relatively large pore spaces present.)

Excellent

Coarse textured sands and loose gravels with low clay and humus content. Also better developed soils with openings left by decaying roots, earthworm or other factors .... - 1

Good

Porous, light colored, granular soils and mixed gravel, containing relatively low percentages of silts and clays (less than 50%).. -3

Fair

Fine compact sands, silts and loams, often containing up to one-half colloidal clay materials. Little evidence of decaying roots or natural soil openings.......................... -5

Poor

Light clays and fine silt loams usually containing upwards of 50% clay. Classification rating of these soils would be modified upwards by the presence of considerable organic matter, decaying roots, etc. .... - 7

WATER HOLDING CAPACITY

Excellent

Deep, well developed, fine textured clay-loam soils with high organic content. Soil aggregates friable and porous.... - 1

Good

Moderately deep well developed medium textured silts and loams with good humus content. Soil aggregates much smaller and more compact .... - 3

Fair

Shallow, undeveloped granular soils with relatively low humus content.. - 5

Poor

Coarse, loose, often light colored, non-organic gravels and coarse sands. (Sands characteristically remain damp due to low capillarity and a rapid drying out of the surface which then serves as an insulation against further evaporation)... - 7

ERODIBILITY

Slight

Deep, fine textured, dark colored, clay and silty clay soils. High clay content indicating cohesive qualities and erosion resistance. Dark color usually indicating high humus content with correspondingly high absorptive qualities and infiltration rates .... 1 - 2

Moderate

Medium textured, moderately deep silt and sandy clay loams with fair organic content. Some loss of erosion resistance qualities although reduced absorptive qualities offset by increased percolation .... 3 - 4

High

Shallow, light colored, undeveloped mineral soils or fine dispersable silts. Such soils have little cohesiveness, absorptive qualities or water holding capacity. Infiltration rates of silt types are not high and soil movement apt to be rapid when runoff occurs .... 7 - 8

Extreme

Slope types of coarse loose granitic gravel and sand containing almost no organic matter. (Due to high infiltration capacity these types are not erosive on low gradients) .....9 - 10

EROSION TRENDS

No appreciable erosion .... - 0

Advanced Improvement

Gully banks and washes well rounded out and stabilizing. The better species of perennial vegetation safely established and making good natural spread. Raw erosion conditions and erosion pavements subdued by cover and surface litter 1 - 2

Recent Improvement

Little or no evidence of recent, active cutting. Gully banks beginning to round off and stabilize but still rather steep and angular. Established plants usually in the nature of annuals, lower scale (non-palatable) perennials or deep rooted shrubs. Invading perennials present on the slopes or in channels but not very densely established. Tiny vegetative terraces and litter accumulations are beginning to mask barren surfaces .... 3 - 4

Slow Decline

Native perennial plants dying out with increasing bare areas becoming apparent. Roots and crowns of remaining plants becoming exposed, plant color sickly or unthrifty as compared to normal green. Volume production below average. Weeds and lower-scale perennial species present in a greater or less degree. Sheet and rill erosion active, erosion pavement becoming apparent. Gully banks if present are apt to be steep or perpendicular .... 7 - 8

Rapid Decline

Large areas of bare ground accompanied by serious soil depletion. Most or all of the better perennial plants gone, the remaining cover represented largely by weeds, lower-scale perennial species or deep rooted shrubs. Remnant plants are hummocked or pedestalled with root crowns exposed high in the air. Sheet and rill erosion active. Erosion pavement apt to be conspicuous, gullies raw and straight-sided, often overhanging due to undercutting at the base .. 9 - 10

EROSION CLASS

Slight

No readily discernible acceleration in soil movement ... 1 - 2

Moderate

Sheet and rill erosion active but less than 50% loss of top soil (horizon A). Gullies, if present, infrequent, (more than 100 feet apart) .... 3 - 4

Advanced

Sheet and/or gully erosion active. Soil losses conspicuous, usually more than 50% of top soil (horizon A) eroded away. Rills or gullies, if present, may be frequent. (Often less than 100 feet apart.) Erosion pavement frequently present and conspicuous.................. 7 - 8

Critical

Destructive sheet and/or gully erosion. Loss of top soil (A horizon) almost complete along with parts of B and C horizons. Gullies when present often large and deep (not crossable by grazing animals.) Erosion pavement usually well developed or bed rock exposed ... 9 - 10

SOIL TYPE RATING CARD

(Tentative form - for field trial and comment)

Factors		Types and Ratings*			
Refer to attached definitions for rating description					
Soil Depth (Horizon A)					
Over 4 inches	1 - 2				
2 to 4 inches	3 - 4				
1 to 2 inches	7 - 8				
Less than 1 inch	9 - 10				
Water Infiltration Capacity					
Excellent	1 - 2				
Good	3 - 4				
Fair	5 - 6				
Poor	7 - 8				
Water Holding Capacity					
Excellent	1 - 2				
Good	3 - 4				
Fair	5 - 6				
Poor	7 - 8				
Slope					
Under 10%	1 - 2				
10 - 30%	3 - 4				
30 - 50%	7 - 8				
Over 50%	9 - 10				
Erodibility					
Slight	1 - 2				
Moderate	3 - 4				
High	7 - 8				
Extreme	9 - 10				
Erosion Trend					
Adv. Impvt.	1 - 2				
Slow Impvt.	3 - 4				
Slow decline	7 - 8				
Rapid decline	9 - 10				
Erosion Class (Correlates with soil removal and gully formation on range form.)					
Slight	1 - 2				
Moderate	3 - 4				
Advanced	7 - 8				
Critical	9 - 10				
Total Rating (Erosion hazard)	- -				

Rating Totals: Erosion Hazard I - 0-15. Land on which good range management will usually meet watershed requirement; Erosion Hazard II - 16-30. Lands requiring strict range management even though it involves high investments in range improvements and protective measures; Erosion Hazard III - 31-40. Lands requiring very strict management and protection that may frequently involve temporary closure; Erosion Hazard IV - over 40. Range lands that should be indefinitely if not permanently closed to grazing as a watershed protection measure.

*Identify area or soil type by name or number as: Oak Flat, Sycamore Bench, Collins Park or #1 - 2 - 3, etc., numbers being particularly appropriate where types are shown on a map.

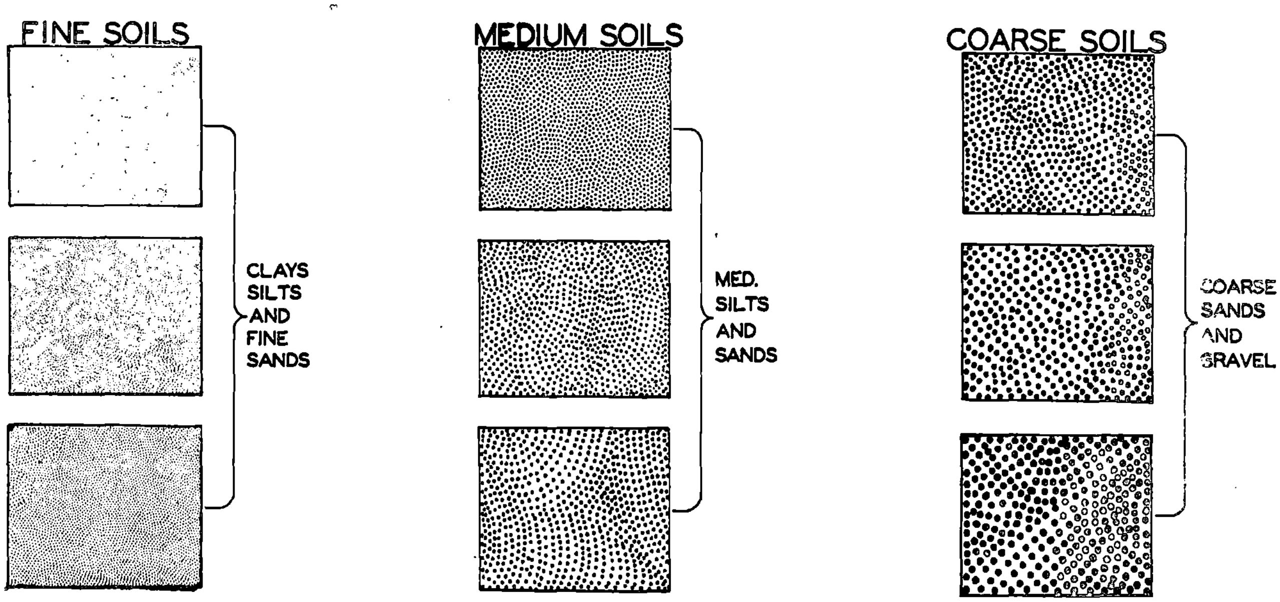
Soil Classification Card

In "Soil Science" Weir points out that soil fractions are grouped as follows:

Above 2 millimeters-----Stone
From 2 mm. to .2 mm.-----Coarse sand
From .2 mm. to .02 mm.-----Fine sand
From .02 mm to .002 mm.-----Silt
Below .002 mi.-----Clay

Unfortunately these measurements are too fine to determine accurately without the aid of a microscope. Therefore an adaptation is offered in the form of the chart shown below. This will serve as a rough but helpful guide for classifying soils as to texture.

In making tests with respect to plant-soil relationships, samples of soil should be selected from the normal "root zone" of herbaceous plants. This is usually about plow depth, 4 to 5 inches below the surface. Soil textures may be determined by spreading samples of the thoroughly dry soil over the chart. Some soils will grade fairly uniform as to size class while others will exhibit very irregular textures. Most of the better developed soils will fall somewhere within the size classifications shown on the chart.



Literature Cited

(1) U. S. D. A. miscl. publication No. 397. "Influences of Vegetation and Watershed Treatments on Runoff, Silting, and Stream Flow."

(2) Southwestern Range Ecology by McGinnies, W. G., Parker, K. W., and Glendening, G. E.

(3) Horton, R. E. Surface Runoff Control. Paper presented at the Upstream Engineering Conference in Washington, 1936.

(4) Kramer and Weaver "Relative Efficiency of Roots and Plants in Protecting the Soil from Erosion." Bull. 12 Conservation Dept., Univ. of Nebraska, 1936.

(5) Watershed and other Related Influences and a Watershed Protective Program. Senate Document No. 12 - Separate No. 5.

(6) Lowdermilk, W. C., Influence of Forest litter on runoff Percolation and Erosion. Jour. of Forestry - April, 1930.

(7) Principles and Indicators for Judging Condition and Trend of High Range-Watersheds. Ellison, Lincoln and Croft, A. R. Intermountain Forest and Range Experiment Station.

(8) NRPB Regional report. Part X. Pecos River Basin, 1942.

(9) The Western Range. Senate Document 199 - 74th Congress.

(10) Bowman, Isaiah. Influence of Vegetation on Land-Water Relationships. Paper presented at the Upstream Engineering Conference in Washington, 1936.

(11) Soil Science. W. W. Weir.

(12) Conditions Influencing Erosion on the Boise River Watershed. U. S. D. A. Technical Bulletin No. 528 by F. G. Renner.

Glossary of Terms as Used in Text

Absorption: The action of water in entering into natural voids in more or less porous material such as soil, wood, organic matter, etc.

Accelerated Erosion: Soil movement that has been speeded up to a greater rate than normally takes place in soil building processes.

Aquifer: A water-bearing bed of earth, gravel or porous stone.

Biochemical: The natural reaction of plant organisms to different chemical stimuli.

Calcium Clay: Clay soils having a high calcium content.

Capillary: Relates to the rise of water in soils through the forces of cohesion and adhesion acting on separate soil particles at minute distances.

Colloids: A glue-like, uncrystallizable substance.

Clay: The name common to various viscous earths, compounds of silica and alumina, sometimes with lime, magnesia, soda or potash and metallic oxides.

Denudation: Loss of vegetative cover.

Friable: Easily crumbled or reduced to powder.

Gravitational: In conformity with the laws of gravity.

Geologic Normal Erosion: Natural soil movement not accelerated by the action of man.

Humus: Vegetable mold. Formed by the partial decay of animal or vegetable matter. Technically, litter does not become humus until it has lost its identity as a given type of plant or animal and been partially incorporated with the soil.

Hydrologic: Pertaining to the laws and properties of water.

Infiltration: The action of water in filtering into natural voids in the soil or other substance, particularly with respect to water entering into the soil mantle. Overlaps with the words "absorption" and "percolation."

Induced Erosion: Accelerated erosion caused by direct or indirect acts of man--such as overgrazing.

Interstice - Interstitial: Minute voids in the soil between the soil particles.

Meteoric Supply: Rain and snow water.

Micro-climate: The climate or atmospheric conditions below the vegetative canopy.

Micro-environment: The combination of soil, climate and biotic factors affecting the immediate environment of seeds and plants.

Muck: Soils containing 20 to 50 percent organic matter.

Parent Formation: The rock or base formation from which soil is formed.

Perennial Stream: A stream having surface flow the year round. A live stream.

Percolation: The passing of water through the soil mantle. Overlaps the word "infiltration" to some extent but also relates more specifically to water passing through the upper soil layers rather than just "infiltrating" into the soil.

Phraetic: Underground sources of water.

Physiologic: Relating to the functions of living organisms.

Soil Compaction: Pressing down or compacting the soil surface by dashing storms, trampling or use of soils when wet.

Soil Development: Soil making--the actual development and improvement of the soil mantle.

Soil Separates: Soil particles or individual grains.

Sodium Clay: Clay soils having an unusually high sodium content.

Suspension: Soil particles so small as float readily in water are in suspension.

Surface Sun Check: Cracks in the soil mantle caused by drying and shrinkage.

Transpiration: The exhalation of water vapor from the leaf surface of plants.

Carson Nat'l Forest

Lew Wallace Lake near Mount Wheeler-one of many small lakes in this vicinity.